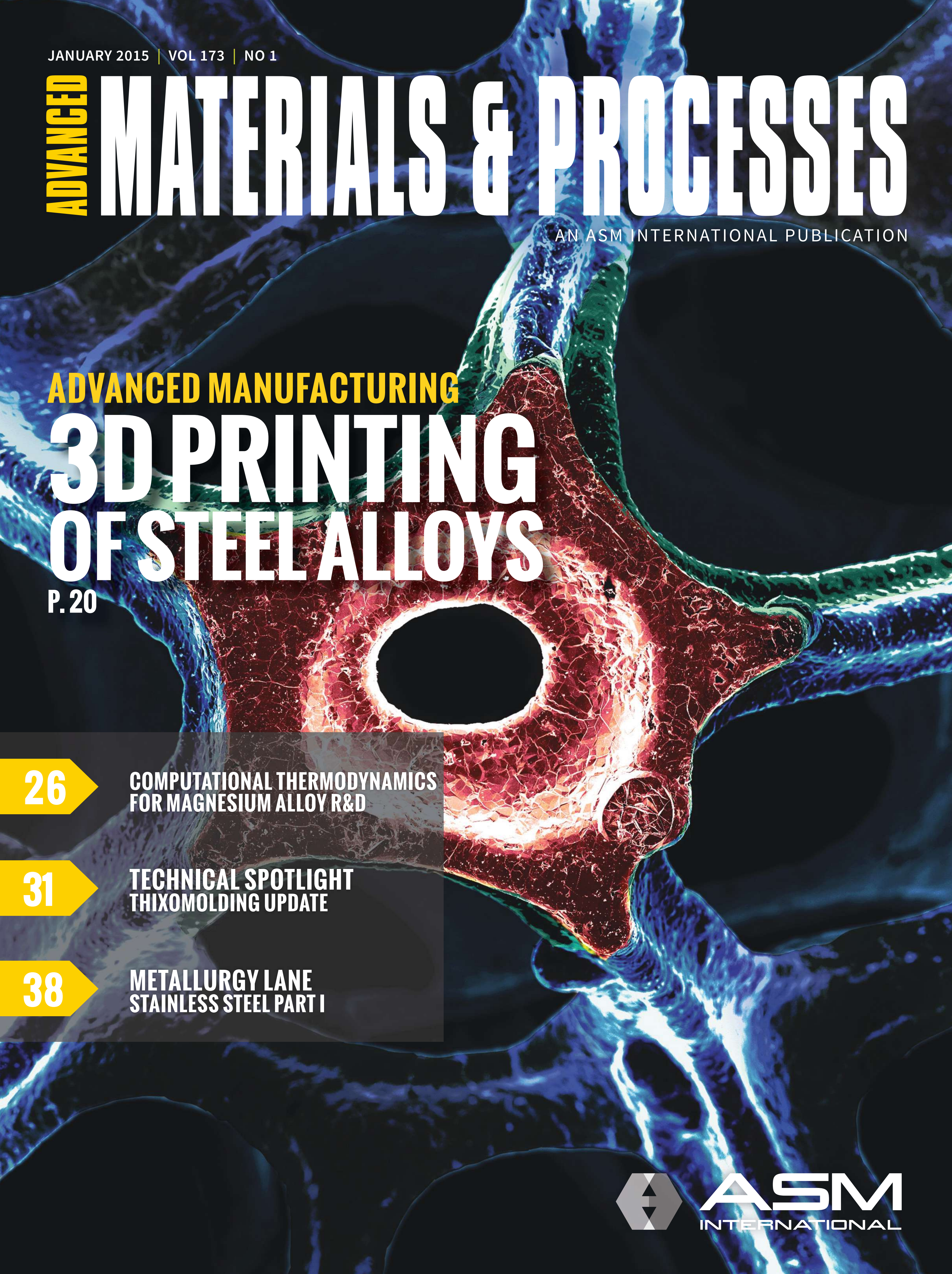
JANUARY 2015 | VOL 173 | NO 1

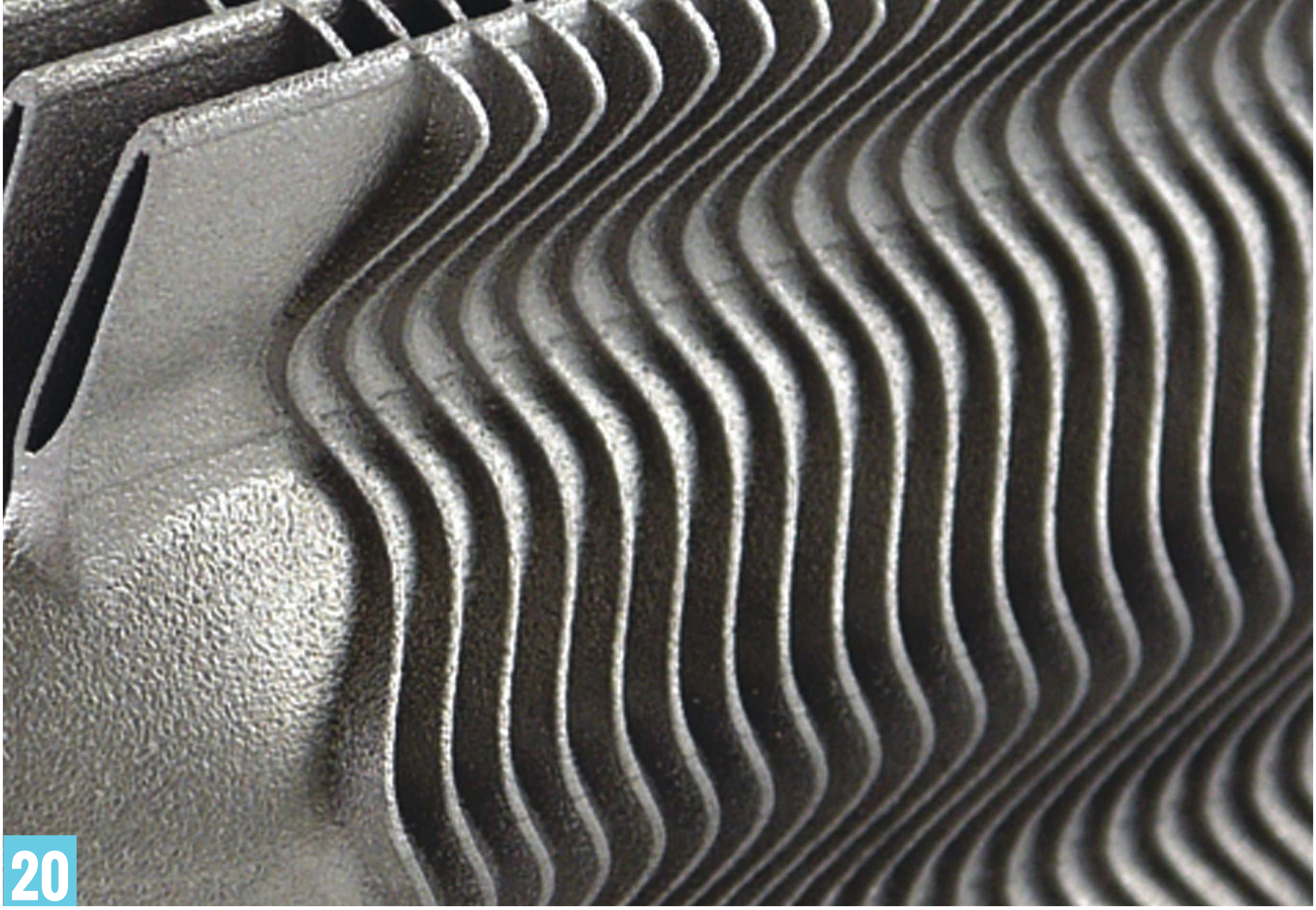
ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION



ADVANCED MANUFACTURING
3D PRINTING OF STEEL ALLOYS

ASM INTERNATIONAL



ADVANCED MATERIALS & PROCESSES

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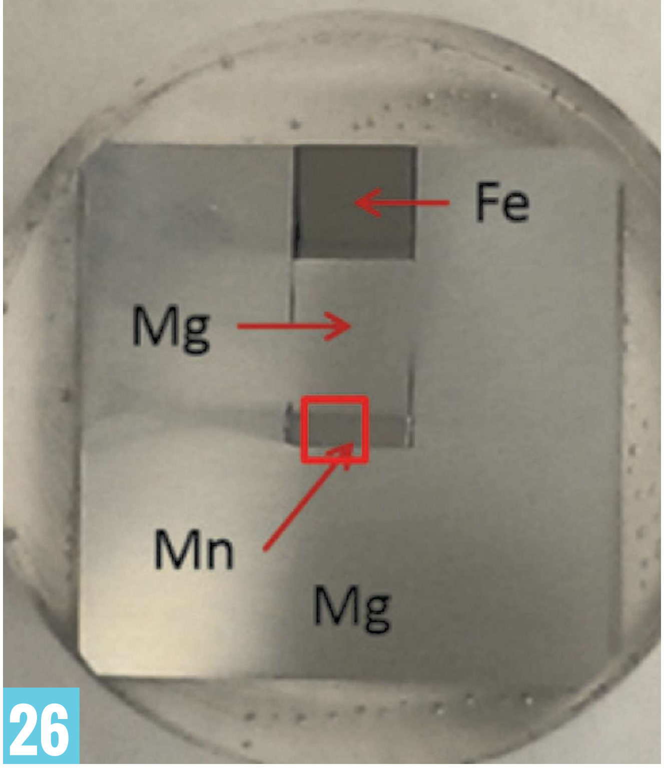
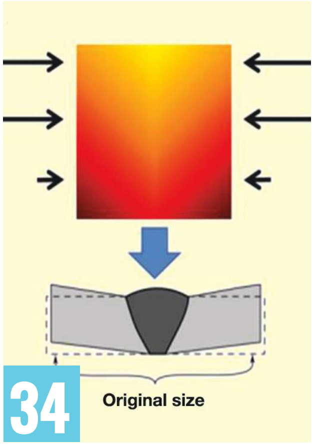
FEATURES





ON THE COVER: *Asteroidea Electrica,* first place winner of the 2014 Department of Engineering photo competition at The University of Cambridge, UK, sponsored by ZEISS. The image is a false colored, low magnification electron micrograph of freestanding graphene foam. Electrically conductive, highly porous, and lightweight, the foam could be used in applications such as energy storage and ultra-lightweight structures. Courtesy of Indrat Aria. www.cam.ac.uk, zeiss.com.

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IMAGINING A HAPPY AND PROSPEROUS NEW YEAR

Happy New Year from ASM International! We are truly excited about the year ahead and hope you are too. With the economy picking up, China doing away with its quotas on rare earths, and recent manufacturing reports posting positive numbers, 2015 is already shaping up to be a solid year. Of course, nothing is guaranteed and we are always skating on the edge of precariousness with pockets of war and unrest around the world. But relatively speaking, things seem to be on a positive trend at least in the world of manufacturing and materials science.

Looking back over the past year, materials engineering was constantly making headlines. From Tesla Motors' "gigafactory" for lithium-ion batteries (construction began last summer in Nevada) to 3D printing of everything from jet engine parts to human tissue, materials were all over the news. We continue to watch aluminum make gains in the automotive industry with Ford's F-150 and the newly announced Jaguar XE, and carbon fiber is making inroads as well, for example in BMW's i3 electric vehicle. Even more promising for carbon fiber adoption are the changes taking place in aerospace designs. Boeing's 787 Dreamliner sports an airframe made of nearly half carbon fiber reinforced plastic and other composites, the Airbus A350 XWB will include fuselage and wings made of carbon fiber composites, and Lockheed Martin's F-35 Joint Strike Fighter will employ 6600 kg of carbon fiber composites per platform. All in all, use of carbon fibers in industrial applications is forecast to rise 12.6% per year through 2018, according to research firm IHS Chemical.

> **"The true sign of intelligence is not knowledge but imagination."**
>
> **–Albert Einstein**

Amazing materials innovations are also taking place in the medical realm. Perhaps among the most promising and interesting developments are new bioabsorbable materials. For example, researchers at Fraunhofer Institute, Germany, are working on metal-ceramic composite suture anchors that "melt away" inside the body after their work is done. The team is using powder injection molding to make the tiny anchors out of a mix of 60% iron alloy and 40% beta-tricalcium phosphate ceramic. The iron corrodes slowly to ensure mechanical strength while the ceramic decomposes quickly and stimulates bone growth to help the body accept the implant. Lab testing is now underway to monitor use and degradation in the human body.

In other news closer to home, ASM has ambitious plans in place for 2015. You've probably noticed our freshly redesigned magazine and we hope you like it! Our goal with the new design is to lend a fresher, more modern look and feel to your favorite materials science news source, but to keep offering the same high quality, trusted technical content. Feel free to let us know how we're doing and if you have any suggestions. For a look ahead at overall Society goals, be sure to read our annual ***Progress Report*** included in this issue. We wish you all a fantastic 2015!

F. Richards

frances.richards@asminternational.org

MARKET SPOTLIGHT

MANUFACTURING EXECUTIVES WORRY ABOUT MINERALS SUPPLY

The National Mining Association (NMA), Washington, recently surveyed senior manufacturing executives highlighting the importance of domestic minerals and metals in manufacturing supply chains. Conducted by Edelman Berland, results show that a large majority of respondents are concerned about mineral availability. The growing global population and development of new technologies and products that rely on greater combinations of minerals have increased the manufacturing industry's demand for raw materials.

Of the large percentage of respondents who note minerals and metals supply as a top concern for their organizations, 91% express worries about minerals and supply chain disruptions outside of their control, citing geopolitics and increasing global demand as the most pressing factors. U.S. manufacturers currently rely on foreign countries for more than half of the minerals and metals they use. Further, most of the executives surveyed also believe minerals and metals demand will only increase in the next five to 10 years. In other findings, 80% of respondents note the importance of sourcing minerals and metals domestically, with the most important reasons cited as job creation, national security, and international competitiveness.

Establishment of new mines in the U.S. currently takes seven to 10 years. According to the survey, 76% of manufacturing executives say the existing permitting process is unacceptable, and 95% believe it to be a serious threat to U.S. competitiveness. Approximately 90% support streamlining the process to less than three years. Other developed nations such as Canada and Australia complete the permitting process in two to three years.

As a result of the survey, NMA will continue to seek public policies that provide a more predictable and efficient permitting process to feed the manufacturing supply chain. The U.S. House of Representatives recently passed *The Strategic and Critical Minerals Production Act* for the third time, and NMA urges the Senate to take up similar legislation to bolster domestic manufacturing industries.

The survey included more than 400 senior executives in the manufacturing industry or industries impacted heavily by manufacturing. Respondents were screened to ensure their role in minerals and metals procurement for their company. *For more information, visit mineralsmakelife.org.*

FAST FACTS ABOUT U.S. MINERALS

- For every job in metals mining, an estimated 2.3 additional jobs are generated.
- The U.S. is 100% reliant on foreign countries for 17 critical and strategic minerals.
- $8.1 billion worth of minerals are imported from foreign countries.
- The U.S. contains $6.2 trillion worth of untapped mineral resources.

Source: naturalresources.house.gov

FEEDBACK

EXPLORING THE MYSTERY OF WROUGHT IRON

I thoroughly enjoyed the historical article about wrought iron ("Metallurgy Lane," February 2014), which I recently came across. Perhaps the author can answer a question that has been on my mind for some time: Why don't wrought iron railroad rails rust away?

Stephen Kurtin

[Your question applies to all wrought iron products. The best answer is that wrought iron contains several percent slag by weight. This slag is elongated in the direction of hot working and is visible only under the microscope. The surface ferrite begins to rust upon exposure to the atmosphere, which leaves the slag particles standing in relief. Eventually, enough slag is exposed at the surface to form a continuous coating that protects the ferrite from further rust. In the April 2014 issue ("Feedback" column), one reader pointed out that a wrought iron pillar* in Delhi, India, has been exposed to the weather for more than 1600 years without rusting. I hope this answers your question.—Charles R. Simcoe]

*ASM Historical Landmark.

We welcome all comments and suggestions. Send letters to frances.richards@asminternational.org.

OMG!

ANATOMICAL BODY PARTS PRODUCED BY 3D PRINTING

The 3D Printed Anatomy Series, developed at Monash University, Australia, is thought to be the first commercially available resource of its kind. The kit contains no human tissue, yet provides all the major body parts required to teach anatomy of the limbs, chest, abdomen, head, and neck. Professor Paul McMenamin says the simple kit could dramatically improve trainee doctors' and other health professionals' knowledge and could even contribute to development of new surgical treatments.

After scanning real anatomical specimens with either a CT or surface laser scanner, body parts are 3D printed either in a plaster-like powder or in plastic, resulting in high resolution, accurate color reproductions.

"Radiographic imaging, such as CT, is a sophisticated means of capturing information in very thin layers. By taking this data and making a 3D rendered model, we can then color that model and convert it to a file format that the 3D printer uses to recreate a body part to scale," says McMenamin. *www.monash.edu.au.*

Michelle Quayle is pictured with part of the 3D Printed Anatomy Series.

Workers build a plastic thatch roof in Ecuador. Courtesy of Flickr, Reuse Everything Institute.

PLASTIC BOTTLES RECYCLED INTO GREEN ROOFS

David Saiia, a professor at Duquesne University, Pittsburgh, came up with an alternative to tin thatched roofs commonly used in South America: Plastic thatch, sourced from soda-bottle waste. The tops and bottoms of the bottles are sliced off and the remaining body is flattened and cut into strips, which are then adhered to a cross-strip using ultrasonic sealing machines. Plastic thatch combines the waterproof qualities of tin with better ventilation. It also allows light to filter in and muffles sound. Further, it is made of local waste materials and will provide livelihood fabricating, selling, and installing roofs, which are expected to last more than a decade. Another bonus, discovered by a pilot in Maqui Pacuna, a nature preserve in Ecuador, is that dust and dirt gradually accumulates on the thatch structures, turning them into naturally occurring green roofs (NOGRs). The soil also helps diffuse the direct sunlight and adds years to the life of the roof. ***duq.edu.***

UNSTICKING NATURE'S STRONGEST GLUE

An international team of scientists led by Newcastle University, UK, and funded by the U.S. Office of Naval Research, has unlocked the secret of one of nature's strongest adhesives—barnacle glue, as seen along the top of this page. Researchers have shown for the first time that barnacle larvae release an oily droplet to clear the water from surfaces before sticking down using a phosphoprotein adhesive. Research associate Nick Aldred says the findings could pave the way for development of novel synthetic bioadhesives for use in medical implants and microelectronics. The research will also be important in the production of new anti-fouling coatings for ships. *www.ncl.ac.uk.*

Are you working with or have you discovered a material or its properties that exhibit **OMG - Outrageous Materials Goodness**?
Send your submissions to Julie Lucko at julie.lucko@asminternational.org.

METALS | POLYMERS | CERAMICS

Alcoa manufactured the world's largest single-piece forged aluminum hull for combat vehicles as part of a joint Alcoa-U.S. Army initiative. Courtesy of U.S. Army.

WORLD'S LARGEST SINGLE-PIECE FORGED ALUMINUM HULL PROTECTS TROOPS

Alcoa Inc., Cleveland, produced the world's largest single-piece forged aluminum hull for combat vehicles to improve troop protection as part of a joint initiative with the U.S. Army. Alcoa manufactured the single-piece part, which was codesigned with the Army Research Laboratory, with the goal of replacing today's assembled hulls.

Based on early modeling and simulation, single-piece underbody structures could provide two times better protection against blasts—such as those caused by improvised explosive devices (IEDs)—than traditional hulls, primarily by eliminating welded seams. In addition to survivability benefits, single-piece hulls can be optimized to reduce vehicle weight and assembly time, and therefore overall cost. The Army is now blast testing the hull to demonstrate its durability. If successful, this initiative could open up numerous opportunities for the military to apply single-piece structures to large combat vehicles and other applications. *alcoa.com, arl.army.mil.*

RADICAL POLYMERS CONDUCT ELECTRICITY

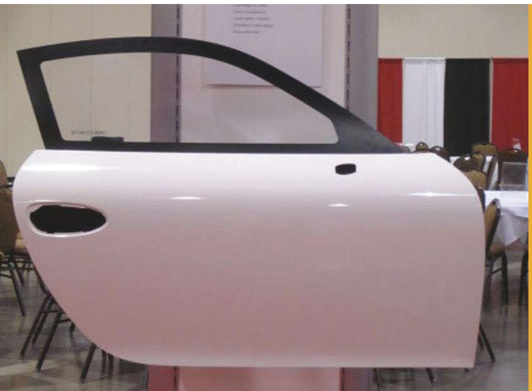
An emerging class of electrically conductive plastics called ***radical polymers*** may bring low cost, transparent solar cells, flexible and lightweight batteries, and ultrathin antistatic coatings for consumer electronics and aircraft. Researchers have established the solid-state electrical properties of one such polymer, called PTMA, which is about 10 times more electrically conductive than common semiconducting polymers. "It's a polymer glass that conducts charge, which seems like a contradiction because glasses are usually insulators," said Bryan Boudouris, an assistant professor of chemical engineering at Purdue University, West Lafayette, Ind.

The polymer is easy to manufacture and resembles Plexiglas. To create it, researchers use a procedure called deprotection, which involves replacing a specific hydrogen atom in the pendant group with an oxygen atom, converting it into a so-called radical group. The oxygen atom in PTMA has one unpaired electron in its outer shell, making it amenable to transporting charge. "You have to control the deprotection process very well because it makes the conductivity vary by orders of magnitude," says Boudouris. The deprotection step can lead to four distinct chemical functionalities of the radical polymer, two of which are promising for increasing conductivity. *For more information: Bryan Boudouris, 765.496.6056, boudouris@purdue.edu, www.purdue.edu.*

SHAPE-SHIFTING MATERIAL TO HELP CORRECT FACIAL DEFECTS

A newly developed shape-shifting material that molds itself to fill gaps in bone while promoting bone growth could more effectively treat defects in the facial region, according to researchers at Texas A&M University, College Station. Melissa Grunlan, associate professor in the university's Department of Biomedical Engineering, is working with colleagues at Texas A&M and Rensselaer Polytechnic Institute, Troy, N.Y. Together they created a polymer foam that is malleable after treating with warm saline, allowing it to precisely fill a bone defect before hardening into a porous, spongelike scaffold that promotes new bone formation.

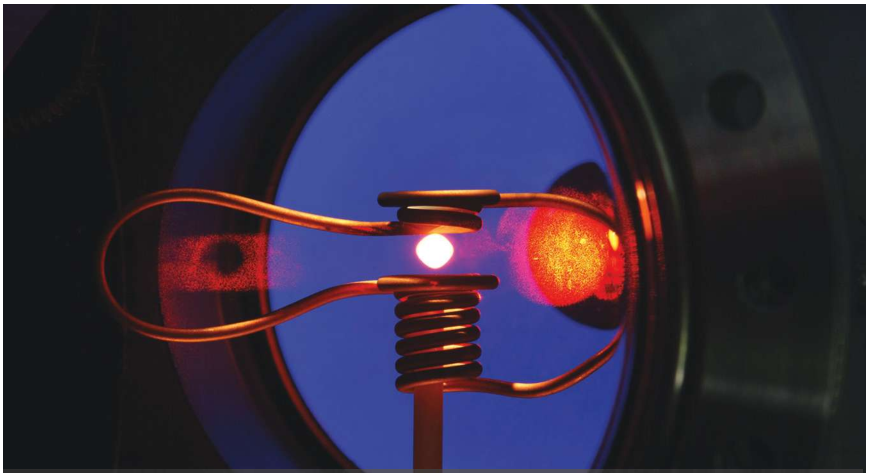
The team envisions the material as a treatment for cranio-maxillofacial bone defects—gaps in bone occurring in the head, face, or jaw areas. The polymer foam acts as a scaffold while promoting healing by allowing bone cells to migrate into the area and repair damaged tissue. Ultimately the scaffold dissolves, leaving behind new bone tissue, says Grunlan. *For more information: Melissa Grunlan, 979.845.2406, mgrunlan@tamu.edu, www.engineering.tamu.edu/biomedical.*



BRIEFS

Momentive Specialty Chemicals Inc., Columbus, Ohio, won the People's Choice Award for the "Most Innovative Composite Part" at the Society of Plastics Engineers Automotive Composites Conference & Exhibition. The winning component was a lightweight, carbon fiber epoxy door and window frame profile produced by Benteler-SGL for 2013 and later Porsche 911 GT3 Cup coupes. *momentive.com.*

TESTING | CHARACTERIZATION



The new electromagnetic levitator aboard the ISS suspends liquid metals in weightlessness as they cool and solidify in ESA's Columbus laboratory. Courtesy of German Aerospace Center, DLR.

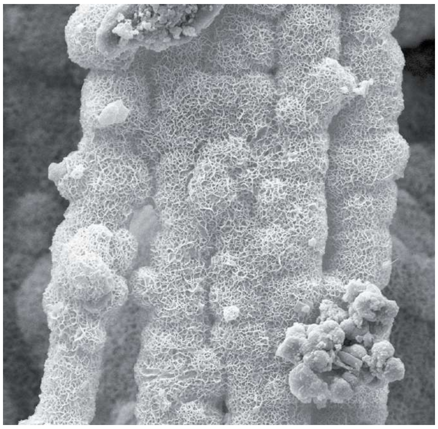
MICROGRAVITY METALS RESEARCH HOLDS PROMISE FOR MATERIALS MODELS

A new European Space Agency (ESA) facility aboard the International Space Station (ISS) will serve as a furnace capable of levitating and heating metals up to 3632°F. The microgravity environment allows the observation of fundamental physical processes that occur as liquid metals cool. ESA's final Automated Transfer Vehicle (ATV-5) mission to the space station delivered the Materials Science Laboratory Electromagnetic Levitator (MSL-EML) and its first batch of new materials science investigations. EML research will provide insight into how liquid metals cool without the influence of gravity or the mold that encases the cooling metals.

EML processes one sample at a time. Each sample is suspended in weightlessness, supported by magnetic repulsion, and then heated to liquefaction. No containers are used to hold the metals during experiments, so measurements can be taken in the purest form. One of the studies in this first batch of EML investigations is called Thermolab. This 15-nation collaboration led by Hans Fecht, a professor at Ulm University, Germany, includes a number of samples with multiple experiments per sample occurring during the next two to five years. Thermolab will investigate temperatures and physical properties of industrial alloys in the liquid phase to help improve models of industrial casting and solidification processes for materials used in aerospace, automotive, and consumer electronics applications. *www.esa.int.*

PHOTO CONTEST CELEBRATES MICROSCOPY

The University of Cambridge, UK, announced the 2014 winners of its Department of Engineering photo competition sponsored by ZEISS, headquartered in Germany. The annual competition aims to show the breadth of engineering research at the university, from nanoscale objects to major infrastructure. First place was awarded to Indrat Aria, for his image entitled *Asteroidea Electrica,* pictured on the cover of this issue. The Electron Microscopy Prize was given to Tanvir Qureshi for his image of a bridge forming in self-healing concrete. The sample was collected from the cement's self-healing zone, where flowerlike bridges effectively expand and heal the cracks. *www.cam.ac.uk, zeiss.com.*

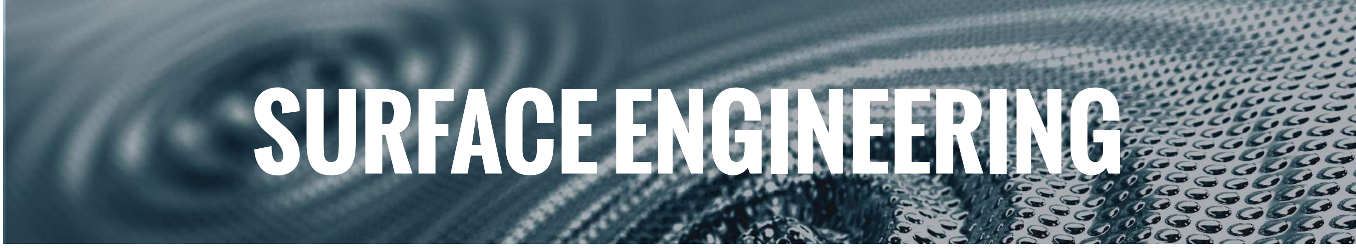


Self-Healing Concrete, the Electron Microscopy Prize winner of the University of Cambridge's annual photo contest. Courtesy of Tanvir Qureshi.

BRIEFS

Neil Sarkar, a researcher at the University of Waterloo's Centre for Integrated RF Engineering (CIRFE), Ontario, received the Douglas R. Colton Medal for Research Excellence from CMC Microsystems for research and development of the world's first single-chip atomic force microscope. The $1000 microscope opens new possibilities in nanoscale research and manufacturing. *www.uwaterloo.ca.*

Single-chip desktop atomic force microscopy on a penny.

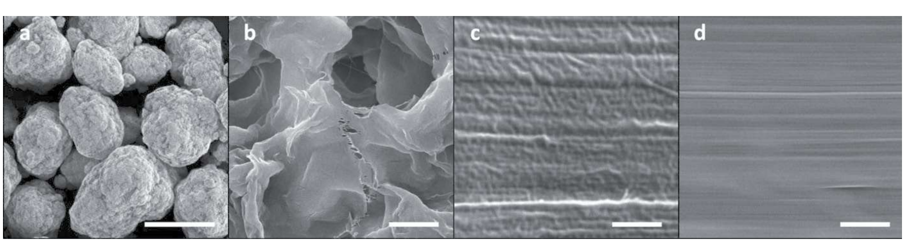


SURFACE ENGINEERING

FABRICATION PROCESS PRODUCES HIGHLY ALIGNED POLYMER FILMS

Researchers from Massachusetts Institute of Technology (MIT), Cambridge, demonstrated a novel automated fabrication process consisting of a three-step sol-gel extrusion, structure freezing and drying, and mechanical drawing process, which results in production of highly aligned polymer films (HAPFs). Although HAPFs are in demand, previous fabrication methods were limited to manual, lab-scale batch processes.

By manipulating the polymers' molecular chains first by disentanglement followed by macroscopic plastic deformation-induced alignment, material properties can be improved. This high-throughput platform uses Couette flow for enhanced chain disentanglement; a constant-force adaptive-thickness mechanical drawing system that aids in uniform film production; and an automated scalable platform—successfully demonstrating a desktop printer-sized fabrication platform for HAPFs in a commercially viable form factor. *mit.edu.*

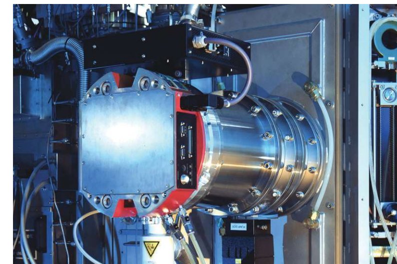


SEM images demonstrate drastic changes in polyethylene surface morphology resulting from fabrication. The initial polymer particulate material resembles tightly wound balls of string (a). Compared to the extruded sample (b), polymer disentanglement as a result of the high shear rate Couette-based extrusion process is evident. SEM images of 50× (c), and 100× (d) drawn films. Film structure is uniform fibrous with minimal defects. Scale bar represents 100 μm (a), and 2 μm (b-d). Courtesy of *Technology.*

VARIABLE GLASS COATINGS TO STOP CONDENSATION ON WINDOWS

Triple glazing is intended to keep as much of the expensive heating energy inside houses as possible, but a drop in outside temperature causes the outermost pane to cool down significantly overnight, and moisture in the air is deposited as condensation, resulting in misty windows.

The Megatron sputtering system, developed by researchers at the Fraunhofer Institute for Surface Engineering and Thin Films IST, Germany, opens the way to the development of entirely new coating systems for a variety of applications. In the case of triple glazing on windows, researchers deliberately contaminate the coating material with niobium in order to make it conductive. "Unlike conventional sputtering systems, Megatron allows us to vary the doping concentration to any required level. It also enables us to increase the coating rate and obtain a smoother surface," says IST group leader Volker Sittinger.



The Megatron lets scientists create new combinations of materials. Courtesy of Fraunhofer IST.

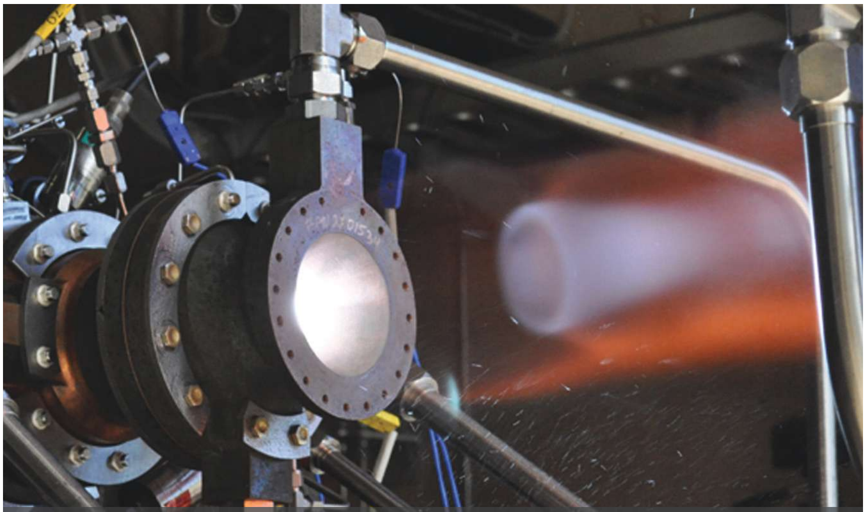
The system allows entirely new coatings to be created by combining materials in a film that cannot be mixed in the form of a target, and were previously impossible to produce. For example, a combination of tungsten and titanium dioxide could be used to create self-cleaning surfaces for interior spaces. When UV light hits a film of pure titanium dioxide, it breaks down any organic particles found there. If the titanium dioxide film is doped with tungsten, the organic dirt particles are broken down and detached when exposed to natural daylight. *www.ist.fraunhofer.de/en.html.*

BRIEFS

Kloeckner Metals, Roswell, Ga., will exclusively distribute physical vapor deposition (PVD)-coated stainless and aluminum sheet products made by Double Stone Steel, whose process of PVD titanium ion coating improves stainless steel performance by enhancing corrosion, scratch, and wear resistance. Compared to electroplating or painting, the PVD process does not discharge gas, water waste, or other residues. *doublestonesteel.com, kloecknermetals.com.*

A TEAM AT **PLYMOUTH UNIVERSITY, UK,** FOUND THAT IN-MOLD GEL-COATING COULD REDUCE STYRENE LEVELS BY MORE THAN 98% PROVIDING A ROUTE TO REDUCED ENVIRONMENTAL IMPACT. *plymouth.edu.*

PROCESS TECHNOLOGY



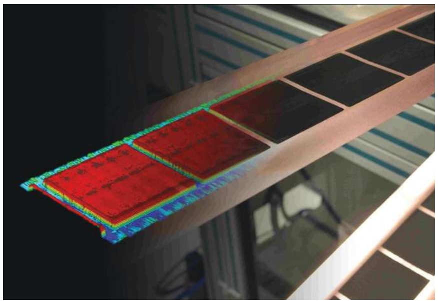
Rocket engine parts made by 3D manufacturing in copper alloy undergo hot-fire testing at NASA Glenn with Aerojet Rocketdyne. Courtesy of NASA.

TESTING 3D COPPER PARTS FOR ROCKETS

NASA's Game Changing Development Program in the Space Technology and Mission Directorate recently co-funded a groundbreaking test series with Aerojet Rocketdyne (AR) at NASA's Glenn Research Center, Cleveland. Working with NASA, AR successfully completed the first hot-fire tests on an advanced rocket engine thrust chamber assembly made of copper alloys. This was the first time a series of rigorous tests confirmed that 3D manufactured copper parts could withstand the heat and pressure required of combustion engines used in space launches. NASA and AR conducted 19 hot-fire tests on four injector and thrust chamber assembly configurations, exploring various mixture ratios and injector operability points. All were deemed fully successful and the work is a major milestone in the development and certification of different materials used in the 3D printing process. *nasa.gov.*

NEW SLOT DIE PROCESS SLASHES BATTERY PRODUCTION COSTS

Scientists at the Karlsruhe Institute of Technology (KIT), Germany, boosted the manufacturing speed of electrode foils coated in batches by a factor of three. This record-breaking performance was achieved by a patent-pending, flexible slot die process that enables production of any pattern with high precision and at high speeds. As a result, lithium-ion



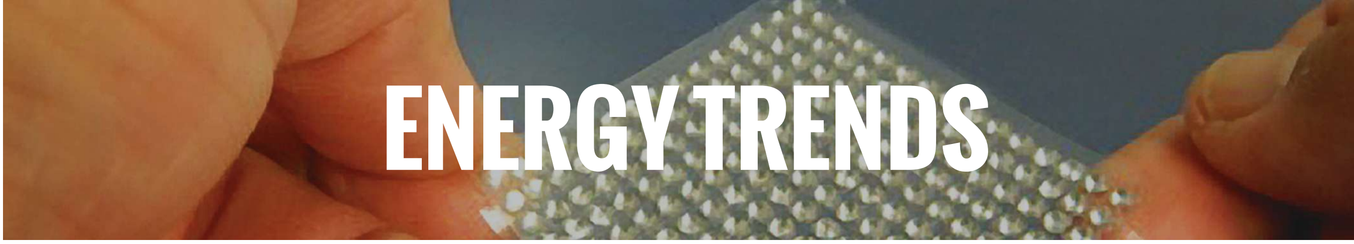
A new process developed by KIT enables coating of electrode foils at record speed. Courtesy of M. Schmitt/KIT.

batteries can be manufactured at much lower costs. After three years of research, the team headed by Wilhelm Schabel and Philip Scharfer of the Thin Film Technology group of the KIT Institute of Thermal Process Engineering increased the speed of intermittent production of the electrode foils representing the actual energy storage systems to 100 meters per minute. Up to now, 25 to 35 meters per minute had been the industrial state of the art. Within the "Competence E" project, scientists developed a revolutionary coating technology that makes it possible not only to produce continuous coatings, but also patterns featuring high precision. *kit.edu/english.*

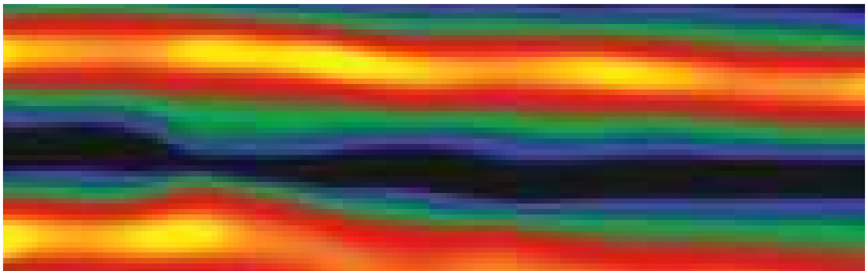
HARPER INTERNATIONAL, BUFFALO, N.Y., FINALIZED A CONTRACT FOR A RESEARCH SCALE HIGH-TEMPERATURE REACTOR TO SUPPORT UNIVERSITY OF COLORADO BOULDER'S DEVELOPMENT OF MAGNESIUM FOR LIGHTWEIGHT VEHICLE PARTS. *harperintl.com.*

BRIEFS

General Electric (GE) will build a $32 million manufacturing facility outside of Pittsburgh to drive innovation and implementation of advanced manufacturing technologies such as digital fabrication, rapid prototyping, and open innovation. The facility will focus on improving capabilities and usage of additive manufacturing across GE while advancing materials sciences and inspection technologies. Construction will be complete by September 2015. *ge.com.*



ENERGY TRENDS



Color-enhanced image reveals how the structure of zinc-antimonide changes as lithium ions enter the anode. Courtesy of Anmin Nie.

FIGURING OUT WHY RECHARGEABLE BATTERIES FAIL

Michigan Technological University, Houghton, researcher Reza Shahbazian-Yassar wants to better map lithium ion's journey from cathode to anode and back again with an ultimate aim to make better batteries, with more power and a longer life. Using transmission electron microscopy, Anmin Nie, a senior postdoctoral researcher in Shahbazian-Yassar's research group, recently documented what can happen to anodes as lithium ions work their way into them.

"We call it atomic shuffling," says Shahbazian-Yassar. "The layered structure of the electrode changes as the lithium goes inside, creating a sandwich structure. There is lots of localized expansion and contraction in the electrode crystals, which helps the lithium blaze a trail."

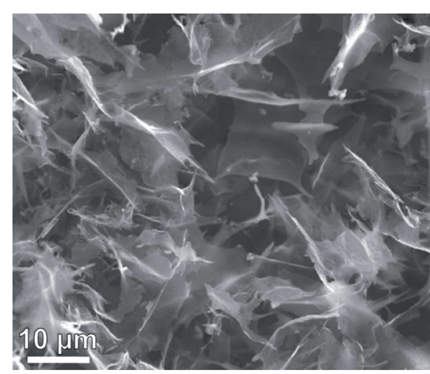
The atomic shuffling not only helps explain how lithium ions move through the anode, in this case a promising new material called zinc antimonide, but also provides a clue as to why most anodes made of layered materials eventually fail. "We showed that the ions cause a lot of local stress and phase transitions," says Nie. *For more information: Reza Shahbazian-Yassar, 906.487.3581, reza@mtu.edu, www.mtu.edu.*

INEXPENSIVE REPLACEMENT FOR RARE METAL AS FUEL-CELL CATALYST

Graphene quantum dots created at Rice University, Houston, grab onto graphene platelets like barnacles attach themselves to the hull of a boat. But they enhance the base material's properties while doing so, making them better than platinum catalysts for certain reactions within fuel cells.

The Rice lab of chemist James Tour created dots known as GQDs from coal last year and now combined these nanoscale dots with microscopic sheets of graphene to create a hybrid that could greatly cut the cost of generating energy with fuel cells.

Researchers discovered that boiling down a solution of GQDs and graphene oxide sheets (exfoliated from common graphite) combined them into self-assembling nanoscale platelets that could then be treated with nitrogen and boron. The hybrid material combines the advantages of each component—an abundance of edges where chemical reactions take place and excellent conductivity between GQDs provided by the graphene base. The boron and nitrogen collectively add more catalytically active sites to the material than either element would contribute alone. *For more information: James Tour, tour@rice.edu, jmtour.com.*



Electron microscope image shows flake-like nanoplatelets made of graphene quantum dots drawn from coal and graphene oxide sheets, modified with boron and nitrogen. The nanoplatelets feature enough edges to make them suitable as catalysts for applications like fuel cells. Courtesy of the Tour Group.

BRIEFS

A123 Systems LLC, Livonia, Mich., a manufacturer of advanced Nanophosphate lithium-ion batteries and systems, completed the sale of its facilities for the production of certain battery materials to Johnson Matthey, UK, a specialty chemicals manufacturer. The facilities in Changzhou, China, produce lithium iron phosphate (LFP), the cathode material that A123 has historically used across its product portfolio. *a123systems.com, matthey.com.*

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Principles of Failure Analysis (3-day)	2/11-13	Foothill Ranch, CA
Thermal Spray Safety Management	2/12	ASM World Headquarters
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Practical Interpretation of Microstructures	3/2-5	Allied High Tech Products Rancho Dominquez, CA
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Elements of Metallurgy	3/9-12	ASM World Headquarters
Metallographic Techniques	3/9-12	ASM World Headquarters
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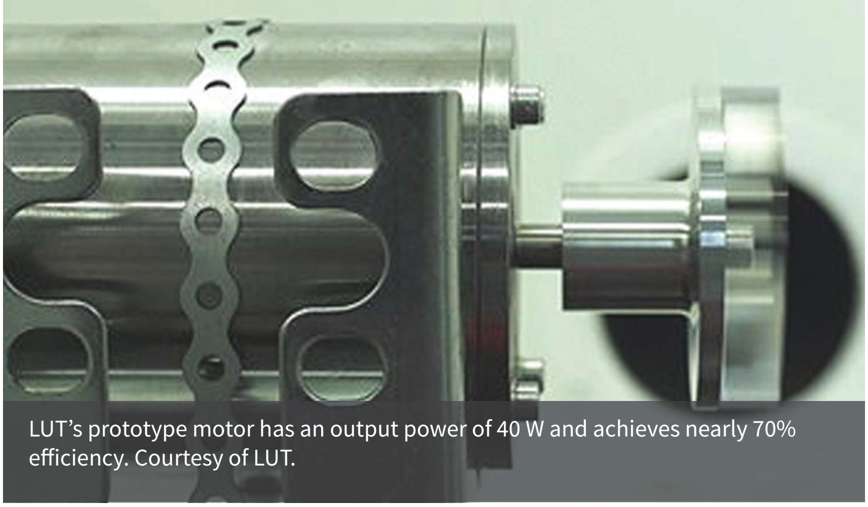


LUT's prototype motor has an output power of 40 W and achieves nearly 70% efficiency. Courtesy of LUT.

ELECTRIC MOTOR DESIGN REPLACES COPPER IN WINDINGS

Researchers at Lappeenranta University of Technology (LUT), Finland, constructed the world's first prototype electrical motor using electrically conductive carbon nanotube yarn in the motor windings, potentially significantly enhancing performance. The test motor has an output power of 40 W, rotates at 15,000 rpm, and achieves almost 70% efficiency.

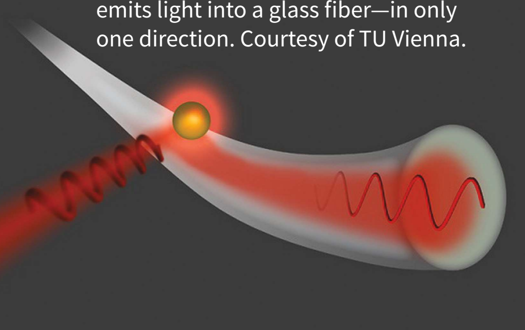
"If we keep the electrical machine design parameters unchanged and only replace copper with future carbon nanotube wires, it is possible to reduce the Joule losses in the windings to half the present-day machine losses. Carbon nanotube wires are significantly lighter than copper and also environmentally friendlier. Therefore, replacing copper with nanotube wires should significantly reduce the CO_2 emissions related to the manufacturing and operation of electrical machines," says professor Juha Pyrhönen. *www.lut.fi/web/en.*

COUPLED WAVEGUIDES ON CHIPS ENHANCE QUANTUM COMPUTING

Commercial devices capable of encrypting information in unbreakable codes are only possible due to recent quantum optics advances, especially the generation of photon pairs—tiny entangled particles of light. An international team of researchers, led by professor Roberto Morandotti of INRS-EMT in Canada, is introducing a new method to achieve a different type of photon pair source that fits into the tiny space of a computer chip.

The method, which generates "mixed up" photon pairs from devices that are smaller than 1 mm^2 in area, could form the core of next-generation quantum optical communication and computing technology. One of the properties of light exploited within quantum optics is photon polarization, essentially the direction in which the electric field associated with the photon oscillates. The research team set out to find a way to directly mix up, or cross-polarize, the photons via a nonlinear optical process on a chip.

To generate the cross-polarized photons, researchers used two different laser beams at different wavelengths—one vertically polarized and another horizontally polarized. The approach, however, came with a potential pitfall: The classical process between the two pump beams could destroy the photons' fragile quantum state. To address this challenge, the team pioneered a new approach based on a micro-ring resonator—a tiny optical cavity with a diameter on the order of tens to hundreds of micrometers—that operates in such a way that energy conservation constraints suppress classical effects while amplifying quantum processes. *For more information: Roberto Morandotti, 514.228.6924, roberto.morandotti@emt.inrs.ca, www.inrs.ca.*



Light hits a gold particle, which then emits light into a glass fiber—in only one direction. Courtesy of TU Vienna.

BRIEFS

Researchers at the **Vienna University of Technology, Austria,** developed a new type of optical switch by coupling gold nanoparticles to ultra-thin glass fibers. They used the property of spin-orbit coupling of light, which enables light to be focused in a single direction. The nanoparticles emit light into these fibers in a specific manner so that the light travels in either the left or right direction. *www.tuwien.ac.at/en.*

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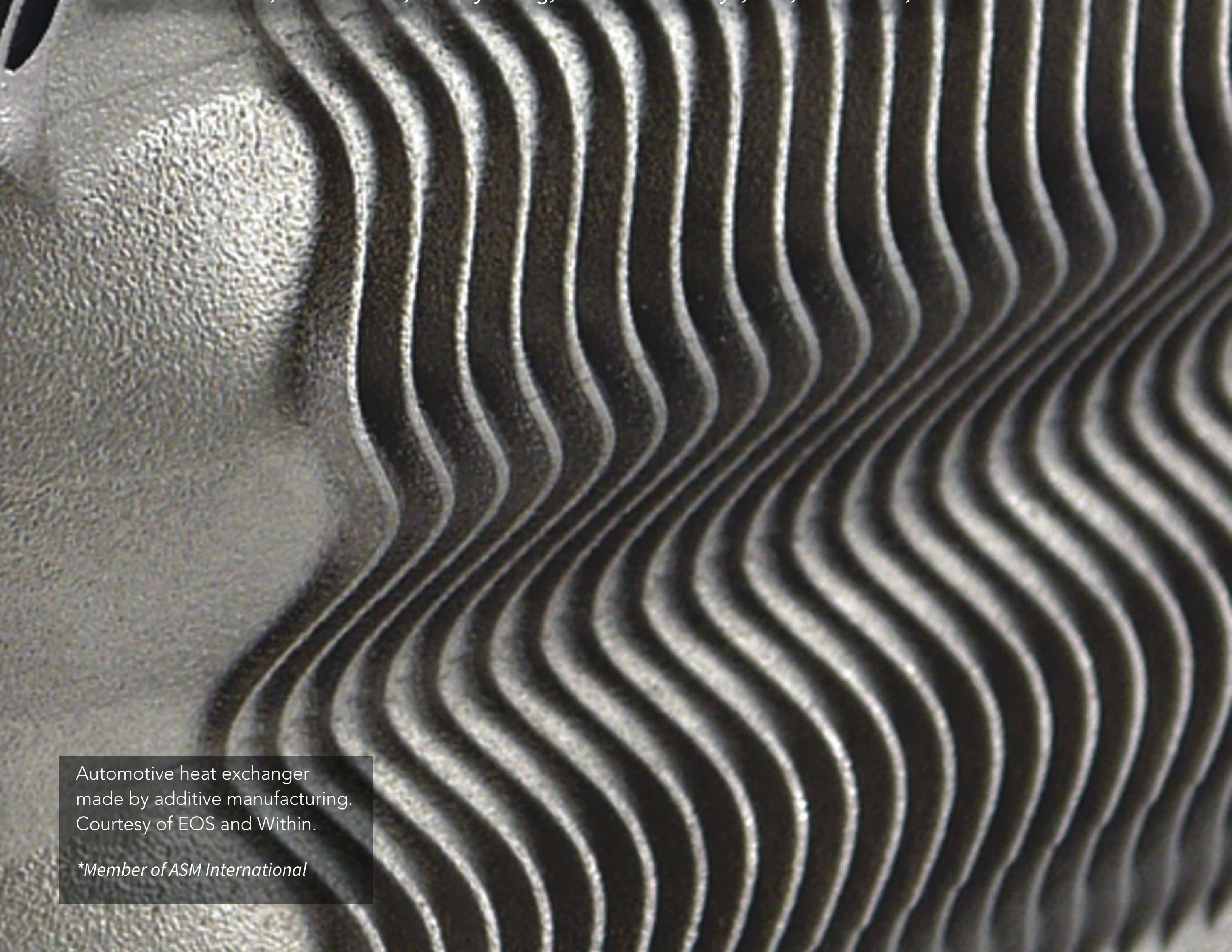
ADDITIVE MANUFACTURING OF STEEL ALLOYS USING LASER POWDER-BED FUSION

In order to expand the choice of materials available for use in additive manufacturing, parameters that consider welding metallurgy, laser powder interaction, and post processing must be developed.

Mahdi Jamshidinia, Alber Sadek, Wesley Wang, and Shawn Kelly, EWI, Columbus, Ohio*



Automotive heat exchanger made by additive manufacturing. Courtesy of EOS and Within.

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Additive manufacturing (AM) is commonly defined as the production of a functional engineering component built one layer at a time from computer aided design (CAD) data. Applicable metal AM technologies produce a volume of material in a layerwise fashion by melting a material feedstock (powder, wire) with an energy source (laser, electron beam, electric arc) that follows a tool path derived from the CAD model.

The ability of AM processes such as laser powder bed fusion (L-PBF) to create complex geometries has caused rapid growth in a number of industries. Energy savings, less material waste, faster design-to-build time, design optimization, reduction in manufacturing steps, and product customization are the most important advantages of AM.

Manufacturers can purchase turnkey solutions from equipment providers that include the machine, process parameters, and even powder. This approach enables production of complicated parts quickly, but the choice of materials available is very limited. Demand for additional materials and a desire to explore other applications requires development of material parameters with an understanding of welding metallurgy, laser powder interaction, and post-process manufacturing steps such as heat treatment. This article describes the outcomes of process development of a steel and stainless steel alloy that are not standard materials for L-PBF equipment.

Two steel alloys including AISI 420 and AISI 4140 were fabricated by an L-PBF process. The influence of both processing parameters and heat treatment on the microstructural characteristics of AISI 420 were investigated. The mechanical properties of AISI 4140 produced by AM were also measured and compared with properties of the conventionally manufactured alloy.

Methods and materials

A schematic of the L-PBF process or direct metal laser sintering (DMLS) equipment is illustrated in Fig. 1[1]. The build platform is preheated to a temperature that is usually below 100°C and a recoating system spreads a thin layer (20-80 μm) of powder over the platform. Next, a laser beam scans the powder bed according to a tool path generated from the part's 3D CAD model. Depending on the L-PBF machine, laser power outputs range from 200 to 1000 W of maximum continuous output. The absorption of laser energy melts the metal powder, resulting in a metallurgical bond between the current and pre-deposited layers. This process continues until the complete 3D design is manufactured layer-by-layer.

Coupon fabrication was performed using a commercially available L-PBF machine (M280 Direct Metal Laser Sintering from EOS, Germany) in EWI's AM laboratory. A liquid argon dewar provided the shield gas and the oxygen level in the process chamber was maintained below 0.1%. Powders were also screened through an 80 μm sieve for use in the M280. General parameters used for the two materials in this study are shown in Table 1.

AISI 420 coupons were heat treated and hardened by heating to 1000°C±10°C with a heating rate of 12°C/min, and holding time of 15 minutes, followed by oil quenching. Tempering at 550°C for 30 minutes achieved high hardness.

Tensile testing of AISI 4140 was performed at room temperature according to ASTM E8 standard using a 0.25-in. diameter gage specimen, with a loading rate of 0.02 in./min (1.27 mm/min). The Charpy notched bar impact test was performed at -18°C according to ASTM E23. Both the tensile and Charpy impact tests were investigated along and normal to the build direction. All tensile and Charpy impact tests were conducted

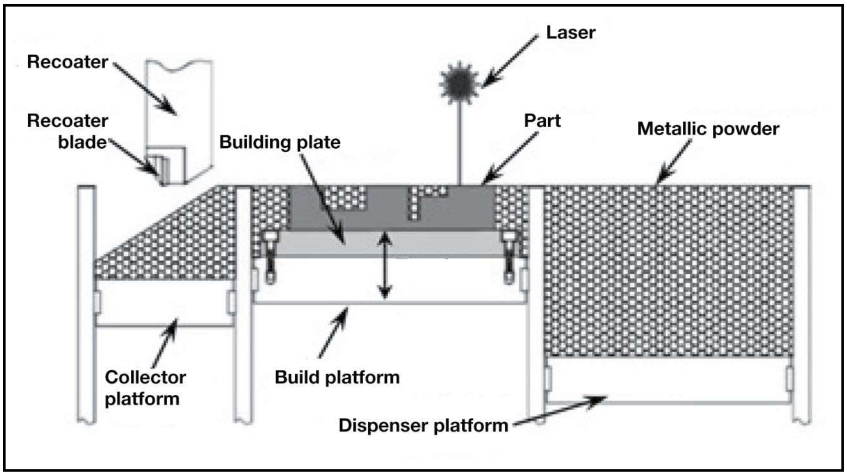

Fig. 1 — Schematic of L-PBF process (left); EOSINT M280 (right)[1].

TABLE 1—PROCESS PARAMETERS USED FOR L-PBF OF AISI 4140 STEEL AND AISI 420 STAINLESS STEEL

Material	Coupon ID	Power, P (W)	Scanning speed, v (mm/s)	P/v (J/mm)	Layer thickness (µm)	Preheat temp. (°C)
AISI 420 stainless steel	a	200	1000	0.200	30	35
	b	300	1000	0.300		
	c	300	800	0.375		
AISI 4140	a	317	1000	0.317	40	80
	b	350	867	0.403		
	c	283	600	0.471		

TABLE 2—CHEMICAL COMPOSITION (WT%), PARTICLE SIZE AND PACKING CHARACTERISTICS OF AISI 4140 POWDER

C	Mn	P	S	Si	Cr	Mo	Fe	N	O
0.44	0.9	<0.01	<0.02	0.21	1	0.21	bal	0.03	0.02
Tap density		4.8 g/cm^3		>270 Mesh		D10	D50	D90	<22 µm
Apparent density		4.0 g/cm^3		5%		34.3 µm	42.2 µm	72.7 µm	0%

TABLE 3—CHEMICAL COMPOSITION (WT%), PARTICLE SIZE AND PACKING CHARACTERISTICS OF AISI 420 POWDER

C	Si	Mn	P	S	Cr	Ni	Mo	N	Fe
0.42	0.54	0.33	0.014	0.01	13.3	0.37	0.06	0.092	bal

on samples with a machined surface finish. Hardness was measured according to ASTM E18 by using a normal load of 150 Kg.

Materials characteristics

Both the AISI 420 stainless steel and AISI 4140 steel powders were produced by Carpenter Powder Products, Reading, Pa. Table 2 shows the chemistry, particle size characteristics, and packing characteristics of the AISI 4140 powder (from vendor certification). A LECO CS400 analyzer performed carbon and sulfur analysis. Nitrogen and oxygen were measured by the inert gas fusion method. The powder had a distribution of -270 mesh/+22µm. Chemical analysis and powder size distribution of AISI 420 are shown in Table 3.

AISI 420 results

Figure 2 compares the microstructure of the as-built AISI 420, where the a, b, and c indexes represent coupons fabricated by low, moderate, and high heat input, respectively. Each individual laser scan is indicated in the metallographic cross-sections by a solidification line. The as-built microstructure exhibits homogenous cellular dendrite structure, which grew epitaxially along the build direction. Some columnar dendrites were large enough to traverse several individual layers.

The as-built microstructure was martensitic in all cases, with some retained austenite. However, depending on the level of heat input, various amounts of austenite were formed with different morphologies. The moderate heat input sample retained much more austenite in the shape of separated longitudinal islands. Each feature consisted of very fine, parallel cylindrical retained austenite grains.

The microstructure of AISI 420 coupons after quench and temper heat treatment is shown in Fig. 3. Heat treatment eliminates the original dendrite structure and fusion boundaries resulting in formation of recrystallized grains. All

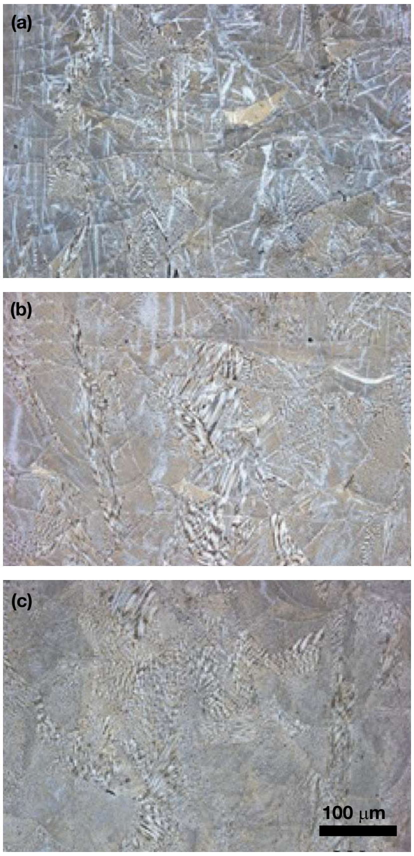

Fig. 2 — Effect of heat input on microstructure of as-built AISI 420 stainless steel: (a) Low heat input (P=200 W, v=1000 mm/s); (b) Moderate heat input (P=300 W, v=1000 mm/s); and (c) High heat input (P=300 W, v=800 mm/s).

Fig. 3 — QT heat treatment influence on AISI 420 microstructure: (a) Low heat input (P=200 W, V=1000 mm/s); (b) Moderate heat input (P=300 W, V=1000 mm/s); and (c) High heat input (P=300 W, V=800 mm/s).

quench-temper (QT) samples reflect formation of fine martensite with precipitation of carbides.

The precipitation of carbides ($M_{23}C_6$) with different sizes was observed. The size and shape of carbides are a function of both heat input and initial microstructure. Lower and moderate heat input (Figs. 3a and b) result in fine carbide particles compared to higher heat input (Fig. 3c), which has very large carbide particles.

Figure 4 shows the influence of heat treatment on the hardness of AISI 420. Heat treatment increases hardness, which can be caused by the formation of a finer microstructure. On the other hand, the volume fraction and size of the carbide particles present in the stainless steel and the amount of retained austenite

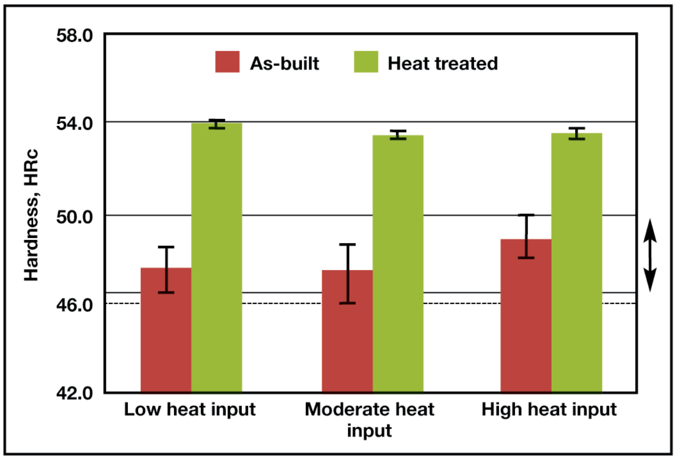

Fig. 4 —Heat input and heat treatment influence the hardness of 420 stainless steel.

TABLE 4—INFLUENCE OF MANUFACTURING PROCESSES ON MECHANICAL PROPERTIES OF AISI 4140

	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Toughness (Charpy energy, J)
L-PBF 4140 steel (as-built)	1365 (XY)	1526 (XY)	13.8 (XY)	34.8 (XY)
	1281 (Z)	1438 (Z)	12.4 (Z)	32.1 (Z)
Conventional 4140 steel	420-900	610-1050	12-15	28-50

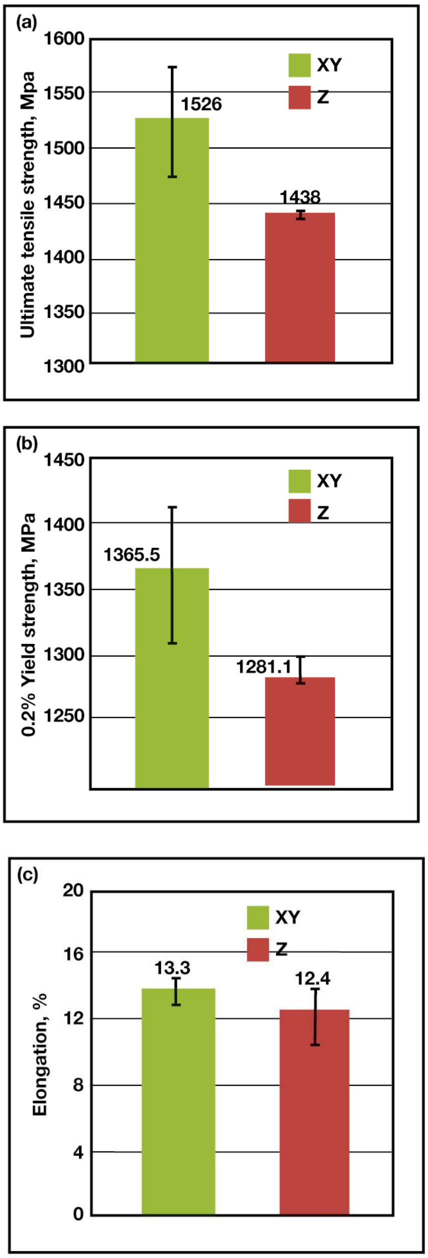

Fig. 5 — Anisotropy in mechanical properties of AM AISI 4140: (a) ultimate tensile strength; (b) 0.2% yield strength; and (c) elongation, %.

play a major role in determining hardness, strength, toughness, corrosion resistance, and wear resistance[2]. Because a higher percentage of spheroidal carbide was formed at a low heat input, maximum increase in hardness was observed in this coupon. The black solid line shows the typical hardness range of AISI 420.

Mechanical properties of AISI 4140

Ultimate tensile strength, 0.2% yield strength, and elongation (%) were measured and compared along the *Z* and normal to *XY* of the build direction (Fig. 5). The difference in mechanical properties is related to the establishment of a unidirectional heat transfer along the build direction in the AM of metals. As a result, elongated grains form along the build direction. Table 4 compares the mechanical properties of additively manufactured AISI 4140 with those of conventional AISI 4140. As-built additively manufactured AISI 4140 exhibits mechanical properties equivalent or superior to conventionally processed (and heat treated) steel. Based on initial microstructural characterization, the formation of small solidification grains and ultrafine cell structures in AM AISI 4140 steel improves mechanical properties. Future work will focus on the microstructural characteristics of an AM AISI 4140.

Conclusions

Studying the additive manufacturing of AISI 420 stainless steel and AISI 4140 steel using a laser powder bed-fusion (L-PBF) process helped develop the corresponding process windows regarding the structural integrity of coupons, where systematic defects such as lack of fusion and porosity were minimized. In both cases (AISI 420 and AISI 4140), densities exceeding 99% theoretical were produced. Through precise control of the L-PBF parameters, it is possible to produce the desired shape of martensitic stainless steel grade 420 with an acceptable microstructure and hardness values. A heat treatment cycle that results in the formation of a fine martensite microstructure with precipitation of spheroidal carbides was designed and implemented. Initial studies of the microstructure reveal a relationship between the formation of an ultrafine microstructure and improved mechanical properties in AISI 4140. **~AM&P**

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Acknowledgment
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COMPUTATIONAL THERMODYNAMICS AND KINETICS FOR MAGNESIUM ALLOY DEVELOPMENT

Computational thermodynamics and CALPHAD modeling prove useful for selecting and developing new magnesium alloys.

Alan A. Luo, FASM, Weihua Sun, Wei Zhong, and Ji-Cheng Zhao*, The Ohio State University, Columbus*

Lightweighting is a well-known strategy for increasing energy efficiency and reducing greenhouse gas emissions. Magnesium, the lightest structural metal, will thus see increased use in a wide range of structural and functional applications for energy generation and storage, propulsion, and transportation[1]. Current industrial applications for magnesium alloys are confined to nonstructural or semi-structural components, due to the limited mechanical properties of conventional Mg-Al-based alloys such as AZ91 (Mg-9Al-1Zn) and AM60 (Mg-6Al-0.3Mn). New magnesium alloys are being developed with higher strength, ductility, and creep resistance at room and elevated temperatures[2-3].

This article summarizes an ongoing effort to establish a scientific foundation of computational thermodynamics and kinetics of magnesium alloys to achieve accelerated design and optimization of these alloys for weight reduction in the transportation industries. All compositions are listed as wt% unless otherwise stated.

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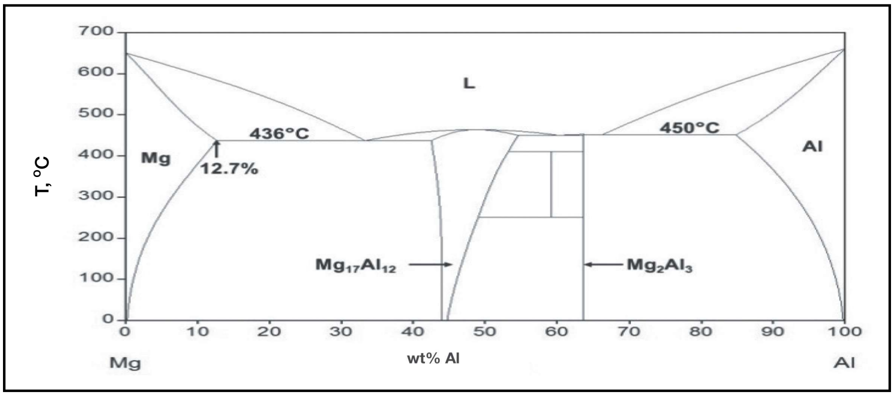

Fig. 1(a) — Calculated Mg-Al phase diagram.

Computational thermodynamics and alloy design

Originated from the early work of Kaufman and Bernstein[4], the CALPHAD (CALculation of PHAse Diagrams) technique—based on computational thermodynamics of alloy systems—has matured over the past few decades. Many commercial software packages, such as Thermo-Calc, FactSage, and Pandat, have become important integrated computational materials engineering (ICME) tools used in the development of new materials and products[4]. This section demonstrates examples of applying computational thermodynamics and CALPHAD modeling in the development of new creep-resistant magnesium alloys using the Pandat code and its PanMagnesium database[5].

Mg-Al system

Aluminum is the most widely used alloying addition in magnesium for strengthening and castability. Figure 1(a) shows the calculated Mg-Al phase diagram. Two eutectic reactions are important to the phase constitution of Mg-Al binary alloys:

1) 450°C $L \rightarrow Al + Mg_2Al_3$
2) 436°C $L \rightarrow Mg + Mg_{17}Al_{12}$

Commercial cast and wrought magnesium alloys (AZ91, AM60, and AZ31) contain less than 10% Al, and the microstructure of these Mg-Al based alloys is generally characterized by formation of the $Mg_{17}Al_{12}$ phase. The low eutectic temperature (436°C) of the $Mg_{17}Al_{12}$ phase limits the application of Mg-Al alloys to temperatures below 125°C, above which the discontinuous precipitation of the $Mg_{17}Al_{12}$ phase leads to substantial creep deformation[2]. Therefore, possible approaches for improving creep resistance in Mg-Al based alloys include: suppressing the formation of the $Mg_{17}Al_{12}$ phase; pinning grain boundary sliding; and slowing solute diffusion in the magnesium matrix.

Mg-Al-Ce system

Earlier experimental work[6, 7] shows that adding rare earth elements (RE) in the form of mischmetal can improve the creep resistance of Mg-Al based alloys, especially when aluminum content is low (less than 4%). This led to the development of AE series alloys, AE42 (Mg-4Al-2RE) and AE44 (Mg-4Al-2RE), where the mischmetal RE generally contains more than 60% Ce (balance La, Nd, and Pr). Figure 1(b) shows the calculated liquidus projection of the Mg-Al-Ce system in the Mg-rich corner. Generally, the liquidus temperature decreases with Al addition (up to at least roughly 10%) and Ce (also up to at least roughly 10%), with the following two type II invariant reactions marked at 871K (598°C) and 835K (562°C), respectively:

1) 598°C $L + (Al,Mg)_2Ce \rightarrow Mg + Mg_{12}Ce$
2) 562°C $L + (Al,Mg)_2Ce \rightarrow Mg + Al_{11}Ce_3$

The calculated solidification paths of AE42 and AE44 alloys using the Scheil model, based on the assumption of complete mixing in the liquid but no diffusion in the solid, are superimposed in the phase diagram shown in Fig. 1(b). Based on simulation results, the solidification sequence for both alloys is as follows:

1) Nucleation of primary magnesium: $L \rightarrow L + Mg$
2) Binary eutectic reaction: $L \rightarrow L + Mg + (Al,Mg)_2Ce$
3) Type II invariant reaction: $L + (Al,Mg)_2Ce \rightarrow L + Mg + Al_{11}Ce_3$
4) Ternary eutectic reaction: $L \rightarrow Mg + Al_{11}Ce_3 + Mg_{17}Al_{12}$

Adding 2-4% Ce to Mg-Al alloys results in the formation of $Al_{11}Ce_3$ in addition to the $Mg_{17}Al_{12}$ phase in the Mg-Al binary system. More detailed calculation

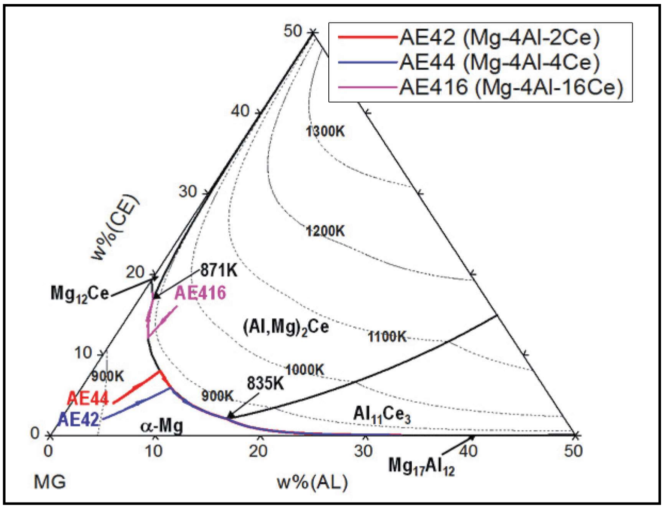

Fig. 1(b) — Calculated Mg-Al-Ce liquidus projection and solidification paths of experimental Mg-Al-Ce alloys.

TABLE 1 — SCHEIL SIMULATION (VOL%) OF MG-AL-CE ALLOYS (BASELINE: AM50 ALLOY)

Alloy	$(Al,Mg)_2Ce$	$Al_{11}Ce_3$	$Mg_{17}Al_{12}$	$Mg_{12}Ce$
AM50	—	—	4.3	—
AE42	0.9	0.2	1.8	—
AE44	2.0	0.1	1.0	—
AE416	9.5	0	0	0.7

shows that 15% Ce is required to completely suppress the formation of the $Mg_{17}Al_{12}$ phase in the Mg-4Al alloy based on the Scheil model[8], which can be used as guidance to design the ternary alloy, avoiding $Mg_{17}Al_{12}$ phase formation in elevated temperature applications. Figure 1(b) also shows the solidification sequence of the AE416 (Mg-4Al-16Ce) alloy as follows:

1) Nucleation of $(Al,Mg)_{12}Ce$ phase: $L \rightarrow L + (Al,Mg)_2Ce$
2) Binary eutectic reaction: $L \rightarrow L + Mg + (Al,Mg)_2Ce$
3) Type II invariant reaction: $L + (Al,Mg)_2Ce \rightarrow L + Mg + Mg_{12}Ce$
4) Binary eutectic reaction: $L \rightarrow Mg + Mg_{12}Ce$

The eutectic temperatures for $Al_{11}Ce_3$, $(Al,Mg)_2Ce$, and $Mg_{12}Ce$ phases are calculated as 560°C, 622°C, and 867°C, respectively, which are all significantly higher than that of the $Mg_{17}Al_{12}$ phase (436°C). The Scheil model was also used to calculate the fraction of phases formed in the three AE alloys according to the above solidification paths. Calculation results are summarized in Table 1 and compared with commercial AM50 (Mg-5Al-0.3Mn) alloy. In AE alloys, 4-5% Al is generally needed for die castability, while it is very expensive to use 16% Ce (e.g., AE416 alloy) to suppress formation of $Mg_{17}Al_{12}$. On the

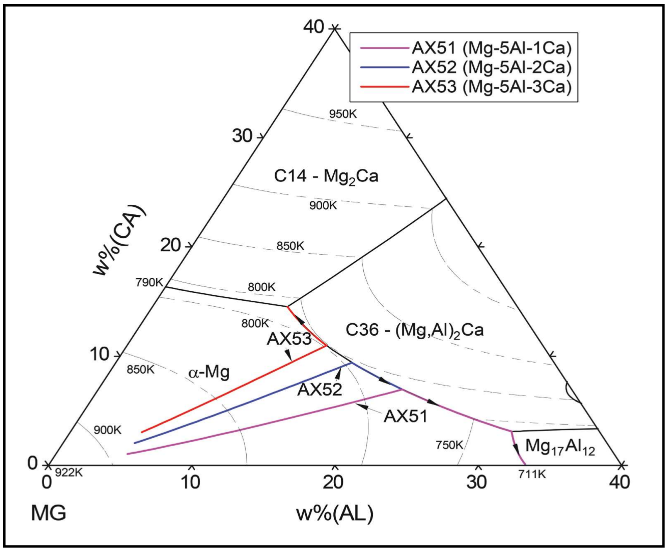

Fig. 1(c) — Calculated Mg-Al-Ca liquidus projection and the solidification paths of the experimental Mg-Al-Ca alloys.

other hand, AE44 alloy has a significantly lower fraction of $Mg_{17}Al_{12}$, and thus, much better high-temperature strength compared with AE42 or AM50 alloy. Therefore, the AE44 alloy was selected for the Corvette engine cradle application where the operating temperature approaches 150°C[9].

Mg-Al-Ca system

The Mg-Al-Ca system was investigated to replace the more expensive AE alloys. Figure 1(c) shows the calculated liquidus projection of the Mg-Al-Ca system, superimposed by the solidification paths of three Mg-Al-Ca alloys, AX51 (Mg-5Al-1Ca), AX52 (Mg-5Al-2Ca), and AX53 (Mg-5Al-3Ca), calculated using the Scheil model. Based on simulation results, the solidification sequence for AX51 and AX52 alloys are as follows:

1) Nucleation of primary magnesium: $L \rightarrow L + Mg$
2) Binary eutectic reaction: $L \rightarrow L + Mg + (Mg,Al)_2Ca$
3) Type II invariant reaction:
$L + (Mg,Al)_2Ca \rightarrow L + Mg + Mg_{17}Al_{12}$
4) Binary eutectic reaction: $L \rightarrow Mg + Mg_{17}Al_{12}$

AX53 alloy has a different ternary eutectic reaction where Mg_2Ca is formed instead of $Mg_{17}Al_{12}$, resulting in a slightly different solidification path:

1) Nucleation of primary magnesium: $L \rightarrow L + Mg$
2) Binary eutectic reaction: $L \rightarrow L + Mg + (Mg,Al)_2Ca$
3) Ternary eutectic reaction :
$L \rightarrow Mg + (Mg,Al)_2Ca + Mg_2Ca$

Both $(Mg,Al)_2Ca$ (C36) and Mg_2Ca (C14) phases have high eutectic temperatures and are beneficial to the creep resistance of Mg-Al-Ca alloys, likely due to the grain boundary strengthening mechanism[10].
The Scheil model was also used to calculate the fractions of $(Mg,Al)_2Ca$, Mg_2Ca, and $Mg_{17}Al_{12}$ phases formed in all the AX alloys according to the above solidification paths, and results are summarized in Table 2. It only requires 2.8% Ca to completely suppress the formation of $Mg_{17}Al_{12}$ in the Mg-5Al alloy[3], which compares to 15% Ce needed in the Mg-4Al alloy. Therefore, Ca is more effective (and less expensive) than rare earth elements (such as Ce) in suppressing the $Mg_{17}Al_{12}$ phase formation in Mg-Al based alloys. AX53 alloy is presently being evaluated by General Motors for automotive powertrain applications.

High-throughput diffusion multiples for atomic mobility database development

While the thermodynamic characteristics and equilibrium phase diagrams for magnesium and its alloys are reasonably well understood, the phase transformation and diffusion behavior of these alloys is not yet clear[11]. Diffusion multiples can be used to generate plenty of diffusion data to fill this gap. A diffusion multiple is an assembly of several metal blocks arranged in a predesigned geometry to allow many diffusion couples and triples to be assembled in a single sample[12,13].

To study major magnesium alloy systems, diffusion multiples provide large amounts of binary diffusion profiles for nine binary systems (Mg-Al, Mg-Zn, Mg-Sn, Mg-Ca, Mg-Sr, Mg-Mn, Al-Zn, Al-Mn, and Mn-Zn) as input to diffusivity extraction. Figure 2(a) shows an example of an Mg-Mn diffusion multiple heat treated at 600°C for 48 hours. No intermetallics layer

TABLE 2 — SCHEIL SIMULATION AND EXPERIMENTAL RESULTS OF SECOND PHASES OF MG-AL-CA ALLOYS (BASELINE: AM50 ALLOY)

Alloy	Scheil calculation, vol%				Measurement, vol%
	$(Mg,Al)_2Ca$	Mg_2Ca	$Mg_{17}Al_{12}$	Total fraction	Total fraction
AX51	2.0	0	2.7	4.7	5.5
AX52	4.1	0	0.9	5.0	5.8
AX53	5.8	0.1	0	5.9	6.2
AM50	—	—	4.3	4.3	4.8

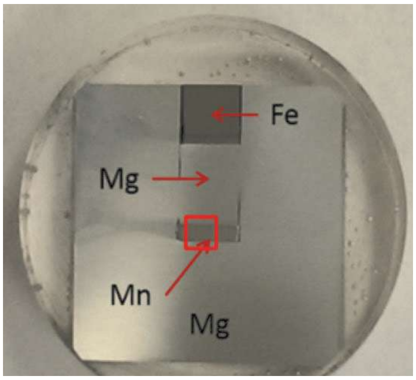

Fig. 2(a) — Mg-Mn diffusion multiple.

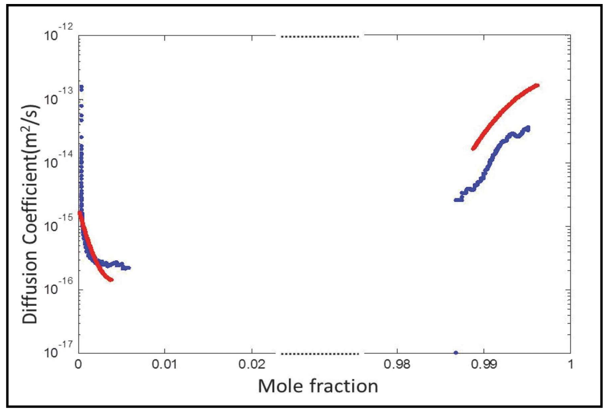

Fig. 2(b) — Comparison of interdiffusion coefficients obtained from the forward simulation[13] (red lines) with those obtained by the Sauer-Freise method[14] (blue lines).

is observed and the concentration profile is measured across the Mg-Mn interface using EPMA (electron probe micro-analysis). By using the forward simulation method[13], the interdiffusion coefficients are extracted, as shown in Fig. 2(b). This is thought to be the first time that the interdiffusion coefficients of the hcp (Mg) phase of an Mg-Mn system are reported. Results clearly show that the forward simulation method can be used to extract impurity diffusion coefficients, whereas the Sauer-Freise method[14] shows wide scatter of data near pure Mg.

A preliminary atomic mobility database of Mg alloys of the Mg-Al-Zn-Mn-Sn-Ca-Sr system is established based on assessment of diffusion data in the literature using the CALPHAD approach. The self-diffusion, impurity diffusion, and interdiffusion coefficients are input to generate the atomic mobility. Empirical methods for estimating the self-diffusion and impurity diffusion coefficients are used to obtain the unavailable data. Most of the literature data are on the diffusion of the Mg-Al binary system below 420°C. Impurity diffusion coefficients of Zn and Sn in hcp (Mg) are reported. For Mn, Ca, and Sr, no experimental data exist yet. Because Al, Mn, Ca, Sn, and Sr do not have a stable hcp structure, the related atomic mobility parameters are estimated using empirical methods. Due to the scarcity of literature data, this preliminary database is still at its early stage and will be improved with ongoing diffusion experiments. Figure 3 shows the calculated interdiffusion coefficients in the Mg rich region of the Mg-Al system along with experimental data. It clearly demonstrates the need for more diffusion experiments to clarify the discrepancy.

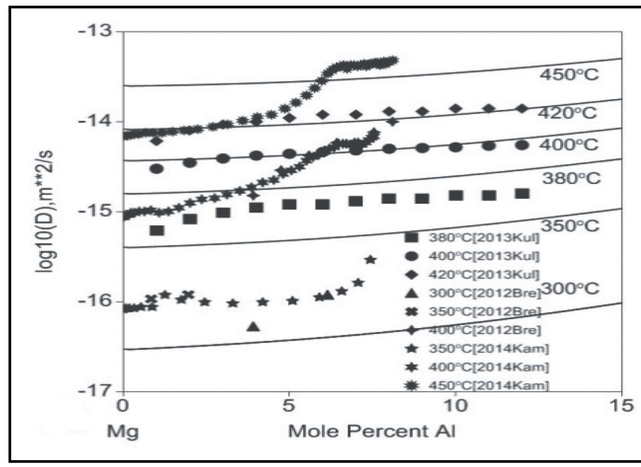

Fig. 3 — Calculated interdiffusion coefficients in the Mg rich region of Mg-Al system along with experimental data[15,17].

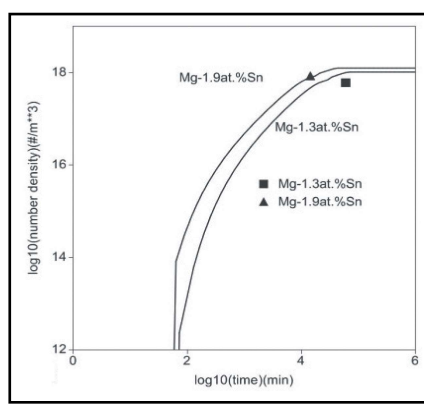

Fig. 4(a) — Predicted number density of Mg_2Sn precipitate in Mg-1.3 at% Sn and Mg-1.9 at% alloys along with experimental data[19].

Precipitation simulation using KWN model

The classic KWN (Kampmann-Wagner-numerical) precipitation model[18] implemented in the PanPrecipitation module of the Pandat software is used to simulate the precipitation of magnesium alloys during the aging process. This model features the capability of simulating nucleation, growth, and coarsening simultaneously. The PanMagnesium thermodynamic database and the preliminary atomic mobility database are used to generate driving force, phase equilibria, and diffusivity for quantitative simulation.

Coupling to the PanMagnesium thermodynamic database and the preliminary atomic mobility database described above, the precipitation of Mg_2Sn at 200°C in two supersaturated Mg-Sn alloys is simulated. The shape of the Mg_2Sn precipitate is not

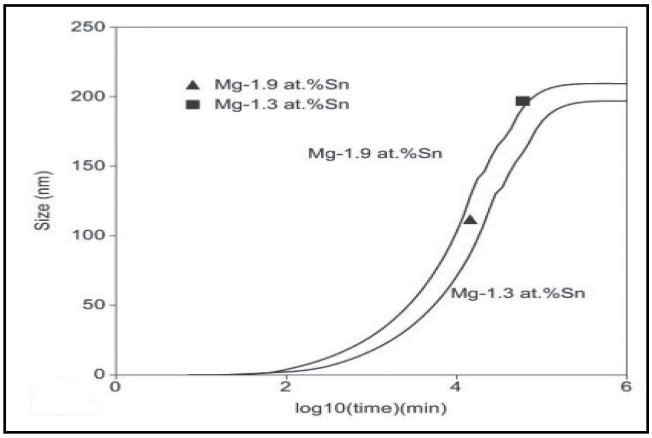

Fig. 4(b) — Predicted radius of Mg_2Sn precipitate in Mg-1.3 at% Sn and Mg-1.9 at% alloys along with experimental data[19].

spherical according to experimental observations[19]. By assuming a shape-preserved growth, the precipitate's shape could be treated as a sphere. The conversion method described by Zhang, et al.[20], is used to calculate the equivalent particle size. Figure 4(a) shows that the calculated number density for the two Mg-Sn alloys is in agreement with the experimental data. Figure 4(b) shows the predicted radius for Mg-1.9 at% Sn alloy at 240 hours is 128 nm, which is consistent with the experimental value of 112 nm. However, for the Mg-1.3 at% Sn alloy, the simulated radius at 1000 hours is 160 nm, which is lower than the experimental value of 197 nm, but still within the experimental error range.

Summary

Computational thermodynamics and CALPHAD modeling, when combined with critical experimental validation, can be used to guide the selection and development of new magnesium alloys. It is demonstrated that Ca is more effective than RE elements (such as Ce) in suppressing the formation of the $Mg_{17}Al_{12}$ phase in binary Mg-Al alloys and introducing more thermally stable phases in the ternary alloys, thus improving their creep resistance and strength at elevated temperatures. AE44 alloy is used in engine cradle applications and AX53 alloy is being developed by GM for automotive powertrain applications.

The diffusion-multiple method, assembling several metal/alloy blocks in a predesigned geometry, allows many diffusion couples and triples in a single sample and is a high-throughput technique for extracting diffusivities for multicomponent alloy systems. A preliminary atomic mobility database of Mg alloys is established based on literature data and estimation from empirical methods. A precipitation simulation based on the classical KWN model has been demonstrated in Mg-Sn alloys, showing good agreement with experimental results.~AM&P

Acknowledgments

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ENVIRONMENTALLY-FRIENDLY INJECTION MOLDING PROCESS MAKES STRIDES

Thixomolding is an environmentally clean and safe commercial process for semi-solid injection molding of magnesium alloys. The process is similar to plastic injection molding but with higher temperature and faster shot velocity (Fig. 1). It was introduced in the 1990s by Thixomat Inc., Ann Arbor, Mich., and cofounders[1] and is based on semi-solid metals discoveries made by Merton Flemings and his students, Robert Mehrabian and David Spencer, at Massachusetts Institute of Technology, Cambridge[2]. It was further adapted to Mg by basic patents held by researchers at The Dow Chemical Co., Midland, Mich.[3] Today more than 465 Thixomolding machines have been built and sold by Japan Steel Works for use in 13 countries.[4]

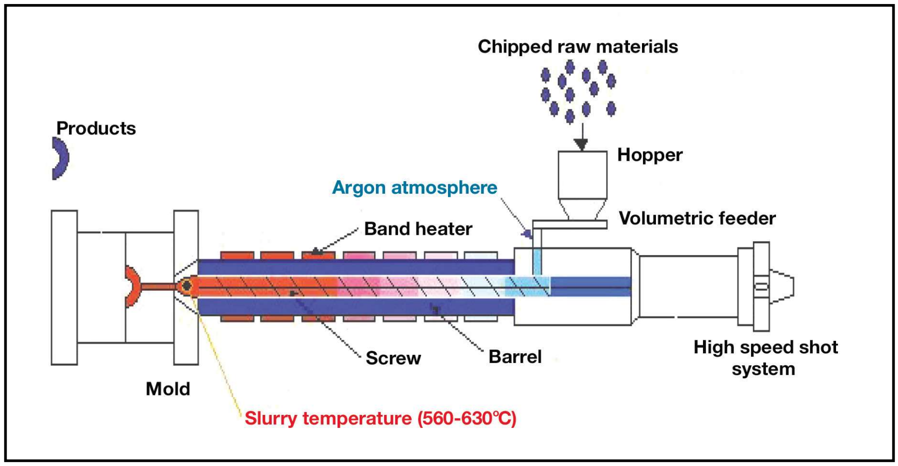

Fig. 1 — Schematic of Thixomolding machine.

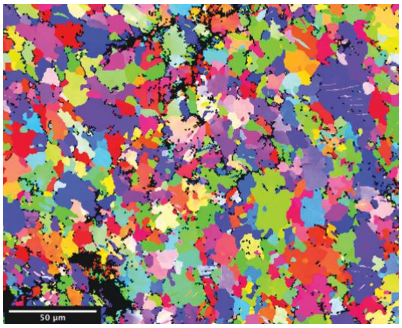

Fig. 2 — EBSD as Thixomolded: Grain size – 5 μm, yield strength – 140 MPa, elongation – 6%, fatigue strength – 70 MPa, toughness – 15 MPam $^{0.5}$, texture – MRD of 1.8 max. Courtesy of Tracy Berman.

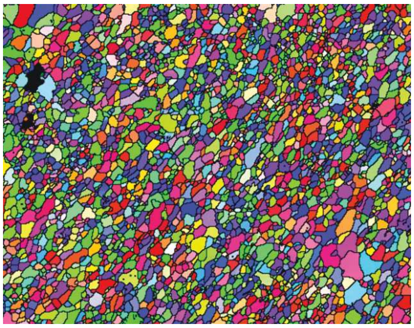

Fig. 3 — EBSD Thixomolded + thermomechanically processed + annealing: Grain Size – 2 μm, yield strength – 250 MPa, elongation – 12%, fatigue strength – 150 MPa, toughness – 28 MPam $^{0.5}$, texture – MRD of 3.7 max. Courtesy of Tracy Berman.

ADVANTAGES AND APPLICATIONS

Since the Thixomolding process was first commercialized more than 20 years ago, several advantages have been identified in comparison to conventional casting. The most important are environmental friendliness and safety, due to no open foundry, no SF6 cover gas, and no sludge or dross. In addition, net shaping of complex parts requires little or no machining. The process offers tight dimensional control, long die life (due to 80°C cooler metal temperatures than die casting), low porosity, and higher ductility and fatigue strength. The process also offers flexibility in part design with the potential to consolidate several parts into one, and features fine as-molded grain size of roughly 5 μm (Fig. 2). Further, Thixomolding is portable—the integrated melting and molding machine can be easily moved to a new site and quickly resume production.

Electronic and communication (E/C) applications in Japan, such as laptop computers, cameras, DLP projectors, and cell phones drove Thixomolding's early use. In the U.S., parts for machine and hand tools, automotive applications, and sports equipment have supplemented the business in E/C parts. Many commercial applications for this technology exist (see sidebar).

Lightweighting is the dominant driver for Thixomolded Mg part use and is supplemented by its

stiffness, electromagnetic shielding, thermal conductivity, and vibration damping virtues. Magnesium compares favorably to aluminum and steel not only for strength and density, but also with regard to bending, torsion, and denting.

Simple part-for-part replacement of die castings offers improved material properties. However, the full benefit of net shape Thixomolding comes from significantly less machining involved and the ability to replace many parts of an assembly with just one Thixomolded component. For example, a 50:1 reduction in subassemblies was accomplished in an electronic check-sorting part application[4].

OTHER PROCESSING AND ALLOY DEVELOPMENTS

In 2007, research efforts began to address value-added products under National Science Foundation sponsorship[6]. The fine grain size and eutectic microstructure of Thixomolded Mg alloys were found to be ideal precursors for applying thermomechanical processing to generate micron-sized grains dispersed with nanometer-sized phases. Thus, strength can be increased by 100 MPa in sheet product, while doubling elongation and fatigue strength and increasing fracture toughness (Fig. 3). In a heat treatment study conducted with researchers at the University of Michigan, low textures were found to improve cold formability[7].

Fig. 4 — DonJoy "OA nano" orthopedic knee brace.

The new technology discovered through this study was adopted in the biomedical market. As one example, the DonJoy "OA nano" Mighty Light orthopedic knee brace was developed, claimed to be the world's lightest OA knee brace (Fig. 4). Other applications for biomedical instruments and aircraft container brackets are being explored.

During an extension of this NSF project, Thixomat's subsidiary nanoMAG invented a new alloy, BioMg 250 bioabsorbable magnesium alloy. It is based on microalloying essential nutrients and bone growth agents for the body and has twice the strength of traditional bioabsorbable polymer implants. The alloy is expected to achieve new bone generation and load-bearing fracture fixing followed by bioabsorption. Company sources say it could eliminate expensive, painful, and infection-prone secondary operations often required to remove titanium or stainless steel implants, for example. Exposure for 52 weeks in vivo (in rabbit knees) at the NSF ERC at the North Carolina Agricultural and Technical State University shows bioabsorption and new bone growth around the BioMg 250 implants (Figs. 5 and 6).

LOOKING AHEAD

Commercial use of Thixomolded Mg is expected to continue to expand in the E/C market, especially in complex shapes at thinner wall sections down to 0.5 mm where its superior bend/dent resistance over aluminum is beneficial. Use in automobiles and the aerospace industry, for lightweighting, can be enhanced by higher temperature Mg alloys such

THIXOMOLDING APPLICATIONS

Automobiles	Electronic/Communication	Sporting goods	Handheld tools
Seat backs	Laptop computers	Sunglasses	Drills
Steering column brackets	Cell phones	Gun scopes	Saws
Mirror parts and brackets	Digital projectors	Fishing reels	Chainsaws
Lazy Susan bins	Digital cameras	Snowboard clamps	Nailers
Foldable car tops	Camcorders	Motorcycle wheels	
Windshield wiper boxes	TV surrounds	Go-cycle bicycle	
Lift gate mechanisms	Walkmans	LED maglite	
Cup holders	MP3 players		
Brackets for trucks	Defense detectors		
LED light fixtures	Radar detectors		
Electronic boxes	Check sorters		
	E-book readers		

as AXJ810-TH—with creep and ignition resistance due to calcium addition. The ongoing quest to improve fuel economy in the automotive sector will also continue to generate renewed interest in lightweight materials.

In the biomedical field, thermomechanically processed Mg is expected to find additional applications external to the body. The bioabsorbable BioMg 250 will now enter a sequence of larger animal tests and clinical studies leading to FDA approval. Commercialization of a bioabsorbable Mg alloy that features the mechanical properties of metals as well as safe, predictable bioabsorption rates will benefit the orthopedic medical practice. ~AM&P

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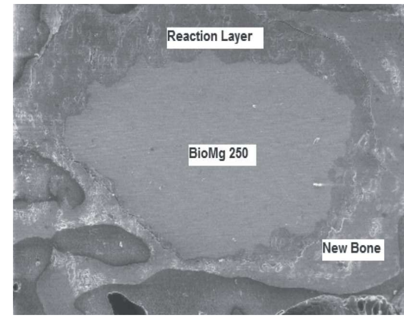


Fig. 5 — SEM showing reaction layer and new bone encapsulating bioabsorbing BioMg 250 in rabbit knee.

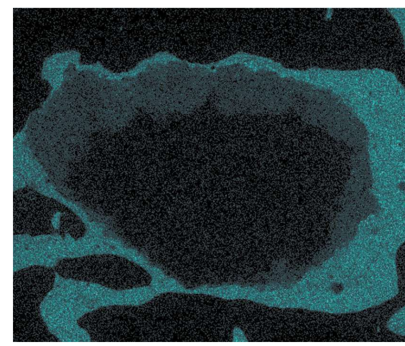


Fig. 6 — SEM-EDS scan of Ca confirming new bone encapsulating bioabsorbing BioMg 250 in rabbit knee.

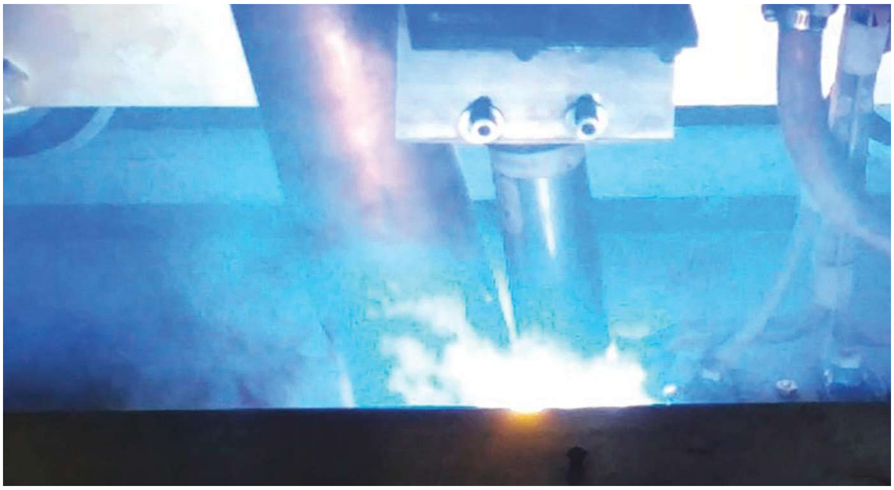
TECHNICAL SPOTLIGHT

HYBRID INDUCTION ARC WELDING

REDUCES WELD DISTORTION AND BOOSTS PRODUCTIVITY

A new welding process known as hybrid induction arc welding (HIAW) or high deposition arc welding (HiDep) uses a hybrid approach to reduce—or even eliminate—weld distortion and greatly increase productivity. Operating directly in front of the arc welding torch, a portable induction coil heats the surfaces of the weld to, or near, the melting point (Fig. 1). Heat generated by the welding arc is primarily used to melt the welding wire. This novel process operates at speeds two to four times faster than conventional arc welding and substantially reduces weld distortion. The technique uses a simple square joint for butt welding, so there is no need for weld joint preparation (such as beveling) for butt joints, even in thick parts.

There has been recent interest in adding auxiliary heat sources such as industrial lasers, arc plasma torches, and multiple arc welding wires/torches to traditional arc welding processes due to their improvement over conventional arc welding for both reducing distortion and increasing welding speed. Systems that use lasers or plasma are referred to as hybrid arc welding processes (e.g., laser hybrid arc welding). For the HiDep system, induction is the best auxiliary heating method because it is much more economical than using a laser, features better performance characteristics, and incurs significantly lower operating and maintenance costs. A portable induction heating system widely used to remove weld distortion and form metal was modified to develop the new system.



HiDep weld in progress—5/8-in. EH-36 marine steel, butt joint 1/8-in. weld gap.

The basic HiDep process features two components—an induction heating coil and an arc welding torch. The high frequency induction heating process uses a metal conductor or coil, which is placed close to the surface of the metal part to be heated. The ac current flowing through the coil induces a current in the part, similar to how a transformer operates. The induced flow of electricity, or eddy current, generates heat by electrical resistance. Water cooling passages inside the coil allow the use of very high current and heat generation is up to 95% efficient. Induction power levels of 35 to 140 kW are possible, so the heat generated by induction can be equal to—or significantly higher than—the welding arc heat.

The new process has been used on steel for butt weld joints up to 0.75 in. thick. For conventional arc welding, this would require a V-groove or bevel edge preparation, but the HiDep system can weld simple square joint configurations, significantly reducing the time and cost of weld preparation. In higher strength/higher fracture toughness steels, such as EH-36 marine steel or A709-Gr 50 structural steels, the strength, ductility, and fracture toughness of the weld and heat-affected zone (HAZ) exceed typical code and standards requirements.

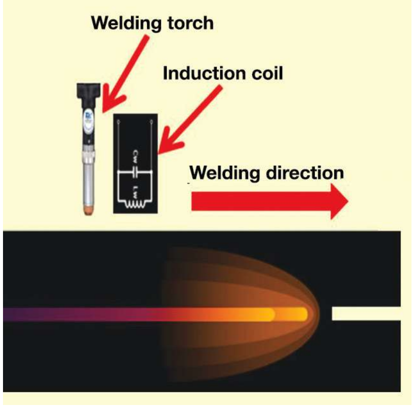


Fig. 1 — Schematic diagram of the HiDep welding process.

Reduced weld distortion

The primary heating mechanism for the welding arc is radiant heat transfer from the arc plasma to the metal components. A significant amount of energy is lost to the surrounding environment. The surfaces of the weld closer to the arc reach a higher temperature than other areas of the weld (Fig. 2a). When the weld cools, the higher temperature regions shrink more than the colder regions (arrows in Fig. 2b), which results in thermal strains called weld distortions.

Induction heat is much more uniformly distributed in the weld joint, heating surfaces nearly to the melting point before the welding arc arrives (Fig. 3a). By using an independently controllable heat source, the hybrid approach offers significant flexibility in the amount and distribution of heat input to the weld. The weld process controller balances the weld heating to provide nearly uniform heating of the weld joint. Induction power levels available can easily equal or exceed the heat energy of the welding arc, which is difficult and expensive to achieve with other hybrid heat sources, such as laser.

When the weld cools, uniform temperature distribution generates uniform shrinkage resulting in nearly equal distribution of thermal strains (arrows in Fig. 3b), and almost zero weld distortion. The image shows a HiDep butt weld that lays flat with nearly zero angular distortion. Using a 3- to 4-in. linear induction coil, the process has been applied to straight butt welds. Balanced heating also virtually eliminates longitudinal distortion for welding large steel plates (Fig. 4).

Mechanical properties

The HiDep welding process demonstrates good mechanical properties in butt welds on plain

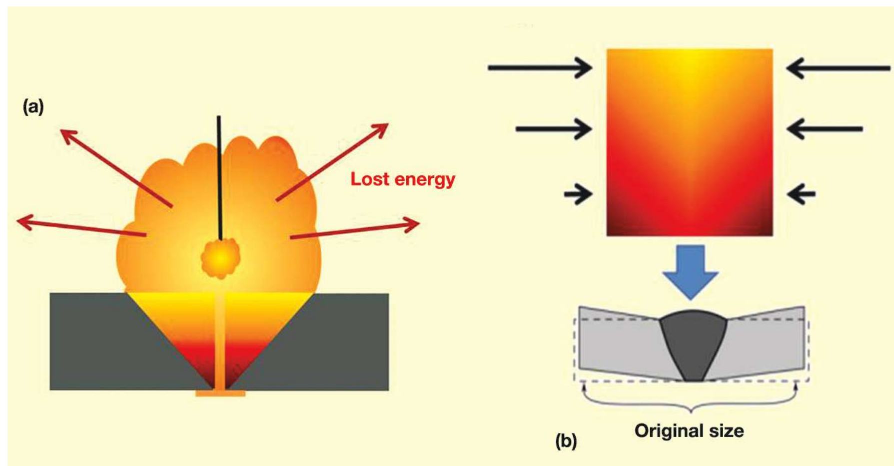


Fig. 2 — Arc welding distortion.

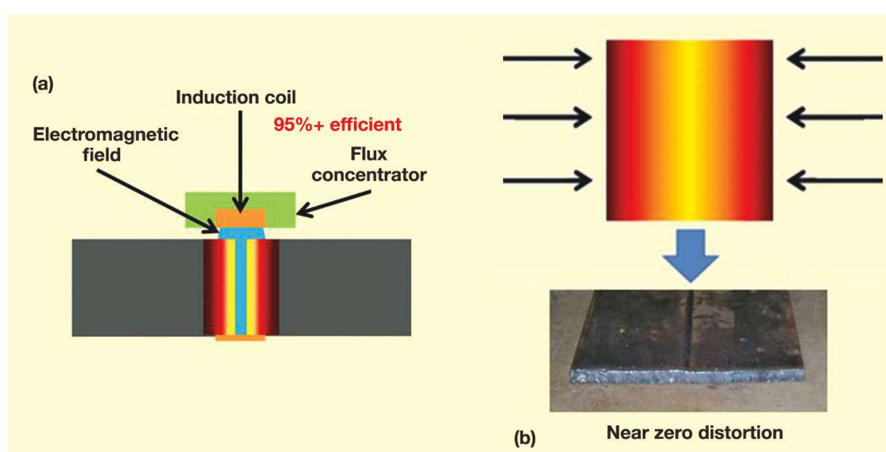


Fig. 3 — HiDep weld—low distortion.

Fig. 4 — HiDep weld—two 8 × 20 ft steel plates.

Metric	Requirement	Results	NAVSEA	A.B.S.	Success
Strength	Yield: 51 ksi Tensile: 70-90	67.4 ksi 88.8 ksi	Passed Passed	Passed Passed	✓
Bend Test	50X Examination	No Defects	Accept	Accept	✓
Fracture Toughness Weld	25 ftlb @ -20° C 20 ftlb @ -40° C	69 ftlb @ -20° C 58 ftlb @ -40° C	Passed	Passed	✓
Fracture Toughness HAZ	25 ftlb @ -20° C 20 ftlb @ -40° C	75 ftlb @ -20° C 43 ftlb @ -40° C	Passed	Passed	✓
Weld Cross-Section	Shape and Size	Meets all Requirements	Passed	Passed	✓

Fig. 5 — Weld test results for qualification to shipbuilding standards.

carbon structural steels such as ASTM A-36. In addition, weld testing on plate thicknesses from 0.20 up to 0.75 in. of higher strength marine (EH-36) and structural (ASTM A709-Gr 50) steels exhibits good strength, ductility, and fracture toughness (Fig. 5). Hobart Metal Cor 6 welding wire was used during testing, along with an argon-10% CO_2 shielding gas mixture.

Process modeling

Any new welding process requires significant testing on a variety of materials, thicknesses, and joint designs. However, HiDep involves different operating characteristics than conventional arc welding. Consequently, significant work has been done to develop numerical models that will provide the capability to apply HiDep beyond application areas that have been tested to date.

The main difference between HiDep and traditional arc welding is induction heating. Numerical models were developed by Gatekey Engineering, Canal Winchester, Ohio, to provide information about the electromagnetic field, as well as heat generation and flow, in HiDep welds. Fully coupled electromagnetic and thermal models of butt joint welds using HiDep have been tested and verified with laboratory data. A complete model for butt welding of steel was also completed (Fig. 6). In addition, models of T-fillet weld joint configurations are in progress. Testing and verification of T-fillet HiDep on selected thicknesses and configurations for steel is expected to be complete by mid-2015. These models include induction coils, weld gaps, and standoff distances of the induction coil from the weld and the pieces being welded. The library of numerical models will eventually be expanded with the goal to include models for several different common weld joints.

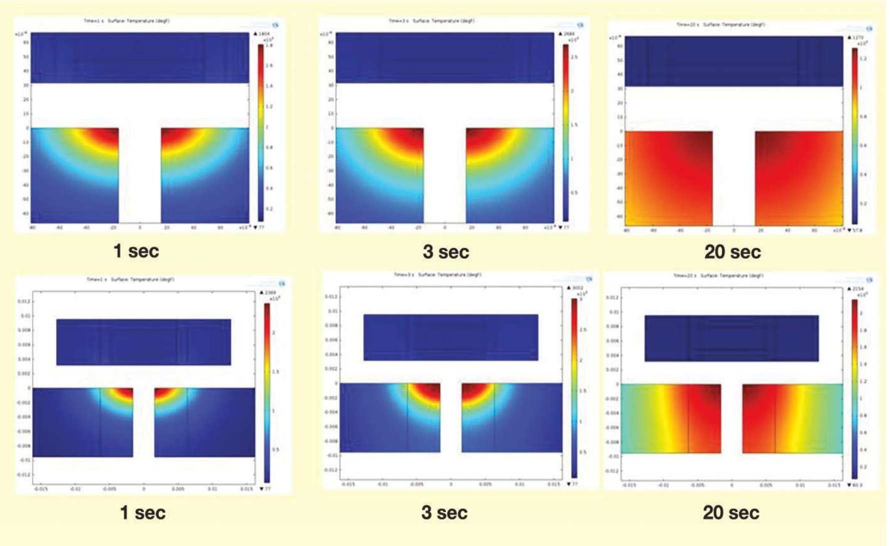


Fig. 6 — Modeling thermal output for 5/8 in. (top) and 3/8 in. (bottom) steel.

Welding equipment

Developers of the HiDep process took advantage of several features in the Miller Auto-Axcess power supply, which is the core of the equipment. Over several years, commercial portable induction robotic systems for weld distortion removal and metal forming were developed and deployed by the HiDep team. These portable systems use the ToccoTron 25 kW and Miller ProHeat 35 kW induction power supplies—equipment widely specified within the welding industry for both welding and weld pre-heating. Consequently, many industrial operations already stock supplies and have trained maintenance personnel available for the primary HiDep equipment. The HiDep controller uses a standard Parker ACR9000 system for power, cooling, and other controls.

Work to develop complete systems, including options for adaptive fill, seam tracking, and coil height stand-off control is ongoing. The welding and induction power supplies and other equipment can be fully integrated into a new system with robotic or mechanized welding operation, or can be retrofitted into an existing system. Commercial systems for butt seam welding of plate will be available in late 2015, and for other joint designs as the process is developed and tested. The induction coil is an EnergynTech system integrated with cooling and power. Ruggedized coil configurations are being tested for butt seam welding.

Looking forward

Work is ongoing to develop other induction coil designs for curved path welding and for other types of weld joint designs including fillet welds. A new

process for cutting metal, hybrid induction-plasma (HI-P) cutting, is also in development. Much of the equipment used for HiDep welding is also used for HI-P cutting. Use of portable robots such as the RTT mobile welding system will further expand the applications for welding in shipbuilding and heavy fabrication, as well as other fields such as large sculptures and specialized architectural structures.

HiDep welding could also be used in the transportation sector to provide very low distortion and increased productivity in both freight and passenger rail car and locomotive fabrication.

Productivity improvement should also be possible for pipelines and large petroleum storage structures.

Development of higher power induction systems for the HiDep process is underway. Initial modeling indicates that single-pass welding of steel plates 0.75 in. thick or greater could reach travel speeds of 10 ft per minute or faster. Induction power levels of 70 to 140kW could substantially increase welding speed for high productivity of heavy steel structures. Heat testing of other materials, including aluminum, stainless steel, titanium, and nickel alloys indicates that it should be possible to use the HiDep process. ~AM&P

Acknowledgment

The National Renewable Energy Laboratory, Department of Energy (DOE) Small Business Innovation Research (SBIR) Program, DOE Energy Efficiency and Renewable Energy Program, Office of Naval Research SBIR Program, National Shipbuilding Research Program, Miller Electric Co., Hobart Brothers Co., A. Zahner Co., EnergynTech Inc., and Gatekey Engineering Inc. all contributed toward development of the HiDep welding process and HI-P cutting process.

For more information: Jerald Jones is chief technical officer, EnergynTech Inc., 11354 W. 13th Ave., Lakewood, CO 80215, 303.279.5286, jejones@energyntech.com, www.energyntech.com.

METALLURGY LANE

Metallurgy Lane, authored by ASM life member Charles R. Simcoe, is a yearlong series dedicated to the early history of the U.S. metals and materials industries along with key milestones and developments.

STAINLESS STEEL: THE STEEL THAT DOES NOT RUST – PART 1

ONE OF THE GREATEST ADVANCES IN MODERN METALLURGY WAS THE DISCOVERY OF A STEEL THAT DOES NOT RUST, WHICH OCCURRED AFTER RESEARCH INTO HIGH CHROMIUM STEELS BEGAN.

French researchers began adding chromium or nickel to heat treated alloy steels during the 1880s and 1890s, while German researchers began combining chromium with nickel in the 1890s. These alloy additions were in the 2% to 5% range and required heat treatment to achieve higher strength.

Before 1895, there was no process for producing low-carbon chromium to be added to iron. Further, controlling carbon is the most important factor in making chromium steels. At this point, German chemist Hans Goldschmidt invented the thermite process, which combines chromium ore with aluminum powder in a heavy-walled container to generate enough heat to separate the chromium metal without carbon contamination. This paved the way to studying alloys with much higher chromium content and low carbon.

The first metals researcher to make use of this new low-carbon chromium was a Frenchman named Leon Guillet. He published his research during 1904-1906 covering the full range of chromium additions that would later be alloys within the commercial range of stainless steel. Guillet's work showed three basic alloy types: One was low carbon with high chromium that could not be hardened and therefore called *ferritic*. Another was higher carbon that could be hardened as any alloy steel and called *martensitic*. Finally, he studied alloys with both chromium and nickel. With sufficient nickel, these alloys were *austenitic*. The first time an all-austenitic microstructure was seen, it occurred at ambient temperature.

These three categories continue to define the range of today's stainless steels. Guillet's studies covered the metallographic and mechanical properties that could be measured during his era. However, he completely missed the fact that some of his alloys were resistant to corrosion in both acids and the normal atmosphere. They were "stainless." Because Guillet was the first to publish on alloys that would later be classified as stainless steels, Carl Zapffe in his classic ***Stainless Steels*** book (ASM International, 1949) awarded him first place in the discovery of these alloys.

Two other researchers who studied iron-chromium and iron-chromium-nickel alloys just a few years after Guillet include the well-known French metallurgist Albert Portevin and an Englishman, W. Giesen. Portevin studied the straight iron-chromium alloys with both low and high carbon. Giesen did most of his work on the iron-chromium-nickel austenitic steels, which had to be low carbon. Both published their results in the same edition of the Iron and Steel Institute's ***Carnegie Scholarship Memoirs***, Vol 1, 1909.

DISCOVERY OF STAINLESS STEEL

The first researcher to discover the groundbreaking property of corrosion resistance was Philip Monnartz of Germany. He began his work in 1908 and published in the journal ***Metallurgie*** in 1911. Quoting from Zapffe, "His research disclosed the stainlessness of stainless steels—and provided as brilliant a piece of work as stands in the literature on stainless steels." First, Monnartz

Hans Goldschmidt invented the thermite process.

Leon Guillet was the first metallurgist to study iron-chromium and iron-chromium-nickel alloys.

Philip Monnartz, the inventor of stainless steel.

determined that when the chromium content exceeded 12%, the steel resisted attack by nitric acid and did not corrode in the normal atmosphere. Next, he found that the metal surface needed to be prepared to form a protective film. This extremely thin film was the formation of an oxide with a combination of iron and chromium when the chromium exceeded 12%. The tightly adherent film prevented further oxidation or corrosion.

He also found that low carbon content is necessary to prevent formation of chromium carbides and that carbon can be controlled by adding stronger carbide formers, such as titanium, columbium, vanadium, molybdenum, or tungsten to form carbides of these alloys rather than of chromium. Finally, Monnartz learned that the addition of 2% to 3% molybdenum greatly increased the corrosion resistance of austenitic stainless. His research provided the basic information for all future developments in practical alloys for the many applications that would develop for stainless steel.

For his discovery, Monnartz must be considered the one true inventor of stainless steel. While the other researchers, especially Guillet, were the pioneers of iron-chromium and iron-chromium-nickel steels, they completely missed the only property that makes these alloys useful today. The mystery is this: How did they not notice that some of their alloys were so difficult to etch for metallographic examination? As Zapffe quipped, "It's not surprising that it took so long to discover stainless steel. What's surprising is that it wasn't discovered sooner."

"IT'S NOT SURPRISING THAT IT TOOK SO LONG TO DISCOVER STAINLESS STEEL. WHAT'S SURPRISING IS THAT IT WASN'T DISCOVERED SOONER."

STAINLESS STEEL APPLICATIONS ABOUND

The years from 1904 to 1911 were a major discovery period, while the following decade witnessed development of alloys for specific applications. The first patent for a stainless steel alloy was German #246015, issued in 1910 to W. Borchers and P. Monnartz, although the first application for stainless steel was for lead-in wires for electric lamp bulbs. The research was done by Christian Dantsizen at the General Electric Research Laboratories in Schenectady, N.Y. Using very low-carbon chromium made by the Goldschmidt thermite process, he developed an alloy containing 14% to 15% chromium and 0.07% to 0.15% carbon. His goal was resistance to oxidation at high temperature and the chromium provided that in a ferritic microstructure. GE would use this alloy a few years later for steam turbine blades.

Another American, Elwood Haynes, worked on stainless steel with a higher carbon content to produce a martensitic microstructure upon quenching from a high temperature. Haynes was an automobile manufacturer with an interest in developing alloys for spark plugs. He had already invented Stellite, a cobalt-chromium-tungsten-carbon alloy used to make hard and wear-resistant surfaces, such as valve seats. He applied for a patent in 1911 on a stainless steel alloy that contained 13% chromium with 0.30% carbon, but it was held up for many years due to interference with a British patent.

The British patent was held by Harry Brearley who had been searching for a wear and corrosion-resistant alloy for gun barrels. This led him to a 13% chromium, 0.25% carbon hardenable stainless steel. He promoted his alloy—the forerunner of AISI 420—for cutlery. It was a natural application for hardened knives and his employers were in Sheffield, UK, the capital of tool and knife making. Brearley is credited with starting the first production of hardenable stainless. The British military found that Brearley's alloy was the answer for aircraft engine exhaust valves and requisitioned the available supply for the years 1914-1919. Thomas Firth and Sons made 50 tons for knives before the war, a production lot considered to be the dawn of the stainless steel industry.

One of the most important patents issued for stainless steel went to Eduard Maurer and Benno Strauss working at the Friedrich Krupp Works in Essen, Germany. Their German patent #304159 issued in 1912 included, for the first time, austenitic stainless steel. One of their alloys contained 20% chromium and 7% nickel. With slight modification, this alloy became 18-8, the single most important stainless steel alloy ever produced.

Elwood Haynes invented martensitic stainless steel with 13% chromium and 0.30% carbon.

Harry Brearley launched the production of martensitic stainless for cutlery and tableware.

Eduard Maurer patented the first austenitic stainless steel in 1912.

For more information: Charles R. Simcoe can be reached at crsimcoe1@gmail.com. For more metallurgical history, visit metals-history.blogspot.com.

ASM's Progress Report to the Membership

The leadership of ASM met earlier this year to conduct the annual discussion and analysis of the society's strategic direction for the upcoming year. ASM's volunteer leadership confirmed and validated the ASM mission, vision, and core values as well as the value proposition, which states:

ASM serves materials professionals, nontechnical personnel and managers worldwide by providing high-quality materials information, education and training, networking opportunities, and professional development resources in cost-effective and user-friendly formats. ASM is where materials users, producers, and manufacturers converge to do business.

ASM Evolution

The theme of the strategic planning session this year was "Vision 2030," which as the title suggests, was focused on helping ASM leadership take a long-range view of the organization. Building off the celebrated 100th anniversary year of 2013, we needed to think about how ASM will continue to evolve and meet the needs of new and existing members as well as the materials profession as a whole. How will the information needs of the profession change? What do we need to do to adapt? What resources are needed? How can ASM be relevant? With our new branding initiative, we've crystallized our position in the market and clarified who ASM is, what we provide, and how we deliver value to our members and customers. That progress will help prospective members find us among the many resources available to them and help us grow stronger as a society.

We are also pleased to report that we've made a renewed effort with government initiatives, a significant "Customer Focus Group" that the ASM Board identified years ago. We have begun to tap into this area, and the results are encouraging. Our role with the American Lightweight Materials Manufacturing Innovation Institute and the "America Makes" Additive Manufacturing initiatives continues to progress. We've been approved by the Department of Energy (DOE) as an Independent Professional Organization, which allowed us to facilitate two workshops this year for the National Energy Technology Laboratory. We are also leading the development of the Thermal Manufacturing Industries Advanced Technology Consortium with a NIST Advanced Manufacturing Technology Consortia grant to develop a consolidated roadmap for the industry, bringing together partner organizations for collaboration. ASM's highly visible role in guiding these key government projects emphasizes our leadership role in the materials science profession. As these projects aim to transform the industry into a highly efficient, productive, and competitive cornerstone of the U.S. advanced manufacturing economy, ASM is proud to be at the helm.

For the full 2015 Strategic Plan, please visit www.asminternational.org/2015Strategicplan

The ASM "Ask"

ASM has launched its first membership drive since 2001 and we believe it will help us recruit new members crucial to our success as well as reenergize our existing members. As part of the campaign, we are "asking" our members to reach out and engage prospective members to join us. The "ask" will lead to new conversations, provide a stronger sense of community and keep members active with ASM. After all, asking is what drives actions that give everyone a higher sense of purpose. Asking initiates.

When we ask people to become members, it's ultimately not about products, services, or savings. It's about relationships and personal interactions. Community has been, is, and always will be our greatest strength and greatest strategy.

Sunniva R. Collins

Dr. Sunniva R. Collins
President 2014-2015

Terry A. Mosier

Terry F. Mosier
Interim Managing Director

ASM's Five Critical Issues:

Life-Long Learning and Education

Life-Long Learning and Education help materials professionals remain technically current so that they may advance their careers at any point in the professional life cycle and contribute to the continued growth and sustainability of the materials community.

Content is Everything Material

ASM International has a strong history as a resource for high-quality materials science and engineering content. Most of this content is created through a framework that enables members and volunteers to capture and share their knowledge and expertise. ASM also has strategic partnerships with other organizations to increase its content assets, which are available to the greater materials community.

With advances in web infrastructure and online networks, and based on ASM's work to create a strong technology environment, ASM has the opportunity to further expand its position to provide content assets that are "Everything Material."

Emerging Technologies

To keep up with the changing needs of our members and other professionals, we have identified materials-related areas where rapid changes and developments are taking place, and we are working to disseminate authoritative and useful knowledge related to these technologies.

Volunteerism

Volunteers provide the energy that propels ASM at the chapter level as well as the national level. Not only are volunteers the leaders of our society, they are the foundation for developing new content, products, and services that our members and customers need and value. As with all volunteer-driven organizations, we face challenges in bringing new volunteers to our society and our chapters — challenges that involve not only attracting new volunteers, but also helping them stay motivated and connected, and feeling appreciated for their contributions.

The achievement of our long-term goals can only be realized through teamwork that includes ongoing member participation through ASM Chapters, Committees, and Affiliate Societies, partnering with ASM staff to develop programs, products, and services that add value to the materials community.

Branding

ASM has a broad and diverse membership, affiliated groups, and product mix. This has sometimes led to a lack of clarity and understanding of the society's value and relevance.

We are working to identify our key differentiating factors and improve how we deliver and communicate their value to the materials community. We will align our communities and build a brand platform that defines our organization's attributes, values, and behaviors.

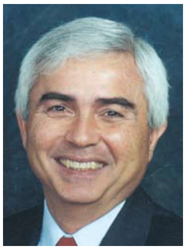
2014-2015 ASM Board of Trustees

ASMNEWS

President Collins Appoints Committee Council Chairs

ASM International President Sunniva R. Collins, FASM, appointed a chair to each of the Society's general committees and councils. All appointments were unanimously approved by the Board of Trustees. Terms began September 1, 2014. Congratulations to all of our ASM International leaders!


Ackerson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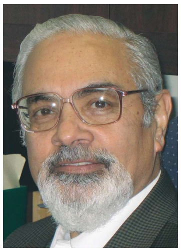
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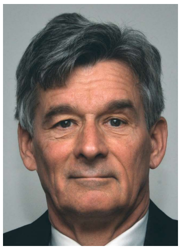
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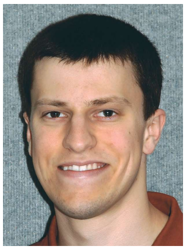

Grice

Committee/Council chairs include:

Mr. Thomas Ackerson, laboratory director, IMR Metallurgical Services, was appointed chair of the Chapter Council.

Dr. Aziz I. Asphahani, FASM, chief executive officer, QuesTek, continues as chair of the Investment & ASM Materials Education Foundation Investment Committee.

Prof. David F. Bahr, FASM, professor, Purdue University, was appointed chair of the ASM & TMS Joint Commission on Metallurgical and Materials Committee.

Dr. Amber Black, applications engineer, Precision Technologies Inc., continues as chair of the Volunteerism Committee.

Prof. Krishan K. Chawla, FASM, professor, University of Alabama at Birmingham, continues as chair of the International Materials Review Committee.

Mr. Craig Clauser, president, Craig Clauser Engineering, serves as Treasurer and chair of the Finance Committee.

Ms. Diana Essock, FASM, president, Metamark Inc., was appointed chair of the Women in Materials Engineering Committee.

Dr. Robert L. Freed, principal consultant, DuPont Co., continues as chair of the Education Committee.

Mr. Daniel R. Grice, manager, metallurgical services, IMR Test Labs, continues as co-chair of the Emerging Professionals Committee.

Dr. Deidre Hirschfeld, manager, Sandia National Laboratories, was appointed chair of the College & University Committee.

Dr. Elizabeth Hoffman, senior engineer, Savannah River National Laboratories, was appointed chair of the New Products and Services Committee.

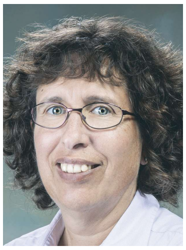
Mr. Jayant Jamuar, techonomist, Mass International, continues as chair of the India Council.

Dr. Padma Kodali, Caterpillar Inc., was appointed chair of the Action in Education Committee.

In This Issue

Submit news of ASM and its members, chapters, and affiliate societies to Frances Richards, editor, ASM News | ASM International 9639 Kinsman Road | Materials Park, OH 44073 | P 440.338.5151 ext. 5563 | F 440.338.4634 | E frances.richards@asminternational.org
Contact ASM International at 9639 Kinsman Road, Materials Park, OH 44073 | P 440.338.5151 ext. 0 or 800.336.5152 ext. 0 (toll free in U.S. and Canada) | F 440.338.4634 | E MemberServiceCenter@asminternational.org | W asminternational.org

HIGHLIGHTS COMMITTEE COUNCIL CHAIRS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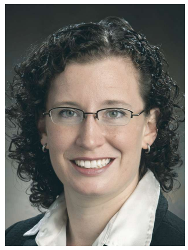
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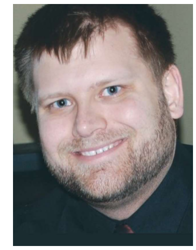
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Lin


Mason


Narayan


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Petrova


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Simpson


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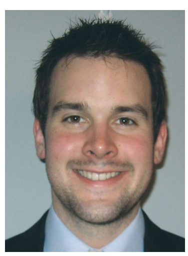
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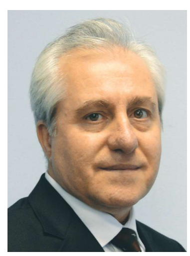

Ulvan


Vander Voort


Wong


Yang


Zinkle

Mr. Chadwick Korthuis, quality leader, Chart Energy & Chemical, was appointed chair of the Technical Books Committee.

Dr. Hua-Tay Lin, FASM, distinguished professor, Guangdong University of Technology, was appointed chair of the Journal of Materials Engineering & Performance Committee.

Mr. Paul Mason, president, Thermo-Calc Software, was appointed chair of the Alloy Phase Diagram Committee.

Prof. Roger J. Narayan, FASM, professor, UNC-NCSU Dept. of Biomed Eng., continues as chair of the Emerging Technologies Committee.

Mr. Michael Niedzinski, director of standardization USA and product development manager, Space and Defense Constellium, was appointed chair of the Aeromat Organizing Committee.

Dr. Roumiana Petrova, FASM, senior university lecturer, New Jersey Institute of Technology, continues as chair of the ASM & MS&T Programming Committee.

Mr. James Powell, mechanical engineer, Solar Turbines Inc., was appointed chair of the Materials Property Database Committee.

Mr. Ron Simpson, materials and processes engineer, Bombardier, was appointed chair of the Web Committee.

Dr. Douglas J. Taylor, consultant, DTX, continues as chair of the Membership Committee.

Mr. Andrew J. Thome, product metallurgist, Carpenter Technology Corp., was appointed co-chair of the Emerging Professionals Committee.

Dr. Erhan Ulvan, technical manager, Acuren Group, was appointed chair of the Canada Council and the Failure Analysis Committee.

Mr. George Vander Voort, FASM, consultant, Vander Voort Consulting LLC, was appointed chair of the Handbook Committee.

Mr. Terry Wong, principal engineer, Rocketdyne, continues as chair of the Content Committee.

Dr. Yu-Ping Yang, senior engineer, EWI, was appointed chair of the AM&P Editorial Committee.

Mr. Steve Zinkle, FASM, chief scientist, Oak Ridge National Laboratory, was appointed chair of the Awards Policy Committee.

ASM Vice President and Board of Trustees Nominations

ASM is seeking nominations for the position of vice president as well as three trustees. The Society's 2016 vice president and trustee elects will serve as a voice for the membership and will shape ASM's future through implementation of the ASM Strategic Plan.

Qualifications: Members must have a well-rounded understanding of the broad activities and objectives of ASM on a local, Society, and international level, and the issues and opportunities that ASM will face over the next few years. Further, they must also have a general appreciation for international trends in the engineered materials industry.

Duties: The duties of board members include various assignments between regular meetings. Trustees also assume the responsibility of making chapter visits and serving as a board liaison to ASM's various committees and councils.

Guidelines: Nominees for vice president must have previously served on the ASM Board, and those selected to serve as trustees should be capable of someday assuming the ASM presidency.

Deadline for nominations is March 15. For more information visit asminternational.org/vp-board-nominations, or contact Leslie Taylor, 440.338.5151, ext. 5500 or leslie.taylor@asminternational.org.

2015 Bradley Stoughton Award for Young Teachers

Winner receives $3000 • Deadline March 1

This award recognizes excellence in young teachers in the fields of materials science, materials engineering, design, and processing.

Do you know a colleague who:

- Is a teacher of materials science, materials engineering, design, and processing
- Has the ability to impart knowledge and enthusiasm to students
- Is 35 years of age or younger by May 15 of the year in which the award is made
- Is an ASM Member

Visit the ASM website at asminternational.org/membership/awards/nominate for complete rules and nomination forms.

ASM INTERNATIONAL

For more than 100 years, ASM International has recognized the achievements of individuals and organizations that contribute to materials science and engineering. Continue this great tradition by nominating candidates for ASM Awards!

We especially look forward to nominations for 2015 Honorary Membership, Distinguished Life Membership, and Medal for the Advancement of Research awards.

Award Deadline: February 1

Edward DeMille Campbell Memorial Lecturer
Distinguished Life Membership
William Hunt Eisenman Award
Gold Medal
Historical Landmarks
Honorary Membership
Medal For The Advancement of Research
Allan Ray Putnam Service Award
Albert Sauveur Achievement Award
Albert Easton White Distinguished Teachers Award
J. Willard Gibbs Phase Equilibria Award
Silver Medal Award
Emerging Professionals Achievement Award

Nomination Forms, Rules and Past Recipient Lists can be found at asminternational.org.

For more information contact:
Christine Hoover
Awards Administrator
christine.hoover@asminternational.org

IMS Joins ASM, HTS and TSS in Seeking Student Members

We're looking for Material Advantage student members to provide insights and ideas to the ASM, HTS, TSS and IMS Boards

We are pleased to announce the continuation and expansion of our successful Student Board Member Programs. In addition to ASM, HTS, and TSS, IMS is also seeking student board members. Each Society values the input and participation of students and is looking for their insights and ideas.

An opportunity like no other!

- All expenses to attend meetings paid for by the respective Society
- Take an active role in shaping the future of your professional Society
- Actively participate in your professional Society's Board meetings
- Gain leadership skills to enhance your career
- Add a unique experience to your resume
- Represent Material Advantage and speak on behalf of students
- Work with leading professionals in the field

Application deadline is **April 1.** Visit asminternational.org/students3 for complete form and rules.

Opportunities Specific to each Society:

ASM International

- Attend four Board meetings (June 17-19, October 5-7 during MS&T15, and March and June 2016)
- Term begins June 1

ASM Heat Treating Society

- Attend two Board meetings (October 19 during HTS Conference and Exposition and spring 2016)
- Participate in four teleconferences
- Term begins in September

ASM Thermal Spray Society

- Attend one Board meeting in the U.S. in November or December
- Participate in two teleconferences
- Receive a one-year complimentary membership in Material Advantage
- Term begins in October

International Metallographic Society

- Attend one Board meeting (August 2-6)
- Participate in monthly teleconferences
- Term begins in August

Board Nominations Sought

Nominations Sought for ASM Thermal Spray Society Board

The ASM TSS Nominating Committee is currently seeking nominations to fill two board member positions. Candidates for these director positions may come from any segment of the thermal spray community, but ideally will have a focus on the service or government research segments. Nominees must be a member of the ASM Thermal Spray Society and must be endorsed by five TSS members. Board members whose terms are expiring may be eligible for nomination and possible re-election on an equal basis with any other candidate. Nominations must be received no later than **March 1.**

Forms can be found at tss.asminternational.org. Contact Luc Pouliot, ASM TSS Nominating Committee Chair, at lpouliot@tecnar.com for more information.

Heat Treating Society Seeks Board Nominations

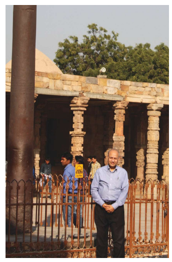
The ASM HTS Awards and Nominations Committee is seeking nominations for three directors, a vice president, a student board member, and a young professional board member. Candidates must be an HTS member in good standing. Nominations should be made on the formal nomination form and can be submitted by a chapter, council, committee, HTS member, or an affiliate society. The HTS Nominating Committee may consider any HTS member, even those who have served on the HTS Board previously. Nominations for Board Members are due **April 1.**

For more information and the nomination form, visit the HTS website at hts.asminternational.org and click on Membership and Networking and then Board Nominations; or contact Joanne Miller at 440.338.5151 ext. 5513, joanne.miller@asminternational.org.

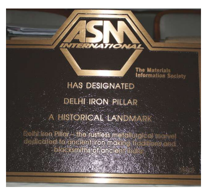
For information on upcoming ASM courses, contact Liz Halderman, ASM Lifelong Learning Representative at liz.halderman@asminternational.org.

Ravindran Dedicates ASM Historical Landmark at Dehli Iron Pillar

Dedication of the Delhi Iron Pillar, a 2013 ASM Historical Landmark, took place in New Delhi on December 3, 2014. The event was organized by the INAE, Archaeological Survey of India, IIM, ASM International, and the ASM India Council.



Prior to the dedication, (from left to right) professors Baldev Raj, FASM, Ravi Ravindran, FASM, and S. Ranganathan reviewed the preparation for the ASM-HLM Delhi Iron Pillar Event at the National Institute for Advanced Studies (NIAS).



Prof. John Gordon Speer, FASM, Receives 2015 J. Willard Gibbs Phase Equilibria Award

ASM is pleased to announce that Prof. John Gordon Speer, FASM, Department of Metallurgical and Materials, Colorado School of Mines, is the 2015 J. Willard Gibbs Phase Equilibria Award recipient. He is cited "for innovative applications of fundamental phase transformation principles in ferrous systems, development of a quenching and partitioning process (Q&P), and contributions to phase equilibria education."

The Gibbs Award was established in 2007 to recognize outstanding contributions to the field of phase equilibria. The award honors J. Willard Gibbs, one of America's greatest theoretical scientists. Gibbs laid the thermodynamics foundations of phase equilibria with his brilliant essay, "On the Equilibrium of Heterogeneous Substances," published in 1876 and in 1878 in the Transactions of the Connecticut Academy.

Prof. Speer will receive his award at MS&T15 in October, in Columbus, Ohio.

HTS Award Deadlines

ASM HTS/Bodycote "Best Paper in Heat Treating" Contest

The ASM Heat Treating Society established the Best Paper in Heat Treating Award in 1997 to recognize a paper that represents advancement in heat treating technology, promotes heat treating in a substantial way, or represents a clear advantage in managing the business of heat treating. The award, endowed by Bodycote Thermal Process-North America, is open to all full-time or part-time students enrolled at universities (or their equivalent) or colleges. The winner will receive a plaque and a check for $2500. Deadline extended to **February 1.**

Nominations Sought for George H. Bodeen Heat Treating Achievement Award

ASM's Heat Treating Society (HTS) is currently seeking nominations for the George H. Bodeen Heat Treating Achievement Award, which recognizes distinguished and significant contributions to the field of heat treating through leadership, management, or engineering development of substantial commercial impact. Deadline for nominations is **February 1.**

First ASM HTS/Surface Combustion Emerging Leader Award to be Presented in 2015

The ASM HTS/Surface Combustion Emerging Leader Award recognizes an outstanding early-to-midcareer heat treating professional whose accomplishments exhibit exceptional achievements in the heat treating industry. The award was created in recognition of Surface Combustion's 100-year anniversary in 2015. Nominations must be submitted to ASM Headquarters no later than **April 1.**

For nomination rules and forms for all three awards, visit the Heat Treating Society website at hts.asminternational.org and click on Membership & Networking and HT Awards. For additional information, or to submit a nomination, contact Joanne Miller at 440.338.5151, ext. 5513, or email joanne.miller@asminternational.org.

HIGHLIGHTS MEMBERS IN THE NEWS

The Power of One | Membership Drive

ASM Helps Reconnect Colleagues and Classmates

Ben Ruchte, Materials Engineer, *Structural Integrity Associates*

ASM is an organization that provides value to its members in a variety of formats ranging from textbooks and classes to workshops and seminars. These are all successful in part due to the wealth of knowledge that has gone into each. That said, it's also important for current ASM members to make a push to bring in new people through the membership drive. This will help maintain the flow of knowledge for years to come.

A great way for current members to help recruit others is by talking to and reconnecting with coworkers and college classmates. For example, I use ASM's *Heat Treater's Guide* on a daily basis for a number of applications at our failure analysis laboratory. Just recently, I reached out to an old college friend and talked with him about using this guide for some work he is doing for a steel manufacturer. I have also reconnected with a former coworker who showed great interest in the microstructural characterization of the high-energy piping components for power plants. I brought to his attention ASM's *Metallurgy for the Non-Metallurgist* course, which he ended up completing.

Not only is it great to catch up with old friends, but ultimately these efforts help to strengthen and rekindle networks of knowledge that can translate to one's own personal career development. Many members and potential members work for a wide variety of companies that provide diverse products and services, but what they have in common is basic engineering principles and an overall understanding of materials.

I believe that materials engineers, scientists, and technicians all have an essential role in developing the materials of today and the future, and are responsible for taking performance to the next level. ASM continues to support these endeavors with a rich history over the past 100 years and remains instrumental in many industries by providing knowledge on enhancements to current materials technologies and by being at the forefront of future technologies.

Narayan wins North Carolina's Top Science Award

In November, Governor Pat McCrory's office announced Prof. Jagdish (Jay) Narayan, FASM, as the winner of the 2014 North Carolina Award in Science. Narayan is the John Fan Family Distinguished Chair Professor in the materials science and engineering department at North Carolina State University. The North Carolina Award is the highest civilian honor bestowed by the state. Referred to as the "Nobel Prize of North Carolina," the award is celebrating its 50th anniversary in 2014. Narayan was recognized for his pioneering contributions in nanomaterials and nanotechnology impacting society, particularly related to thin film science for epitaxy across the misfit scale, laser processing of novel functional materials, and control of defects and interfaces in nanostructured materials to improve performance and efficiency.

Governor Pat McCrory presents award to Prof. Narayan.

Chen receives 2014 Materials Theory Award

The Materials Research Society (MRS) named Long-Qing Chen, FASM, professor at The Pennsylvania State University, as the recipient of its Materials Theory Award for his "pioneering work in the development of the phase-field method and its applications in the computational modeling of mesoscale structures and their dynamics in inhomogeneous materials." The award, endowed by Toh-Ming Lu and Gwo-Ching Wang, recognizes exceptional advances made in materials theory.

Cramb named President of Illinois Institute of Technology

The Board of Trustees of Illinois Institute of Technology (IIT), Chicago, unanimously elected Alan W. Cramb, FASM, to be the ninth president of

the university. He has served as provost and senior vice president for academic affairs since 2008 and will succeed John L. Anderson on August 1. Cramb is also the Charles and Lee Finkl Professor of Metallurgical and Materials Engineering at IIT. He received his B.Sc. with honors in metallurgy from the University of Strathclyde in Glasgow, UK, and his Ph.D. in metallurgy and materials science from the University of Pennsylvania. Cramb is the author of more than 200 publications, holds two patents, and is the recipient of many academic and industry honors.

Alpha Sigma Mu Distinguished Life Member Award Honors Singh

Dr. Mrityunjay Singh, FASM, chief scientist, Ohio Aerospace Institute, Cleveland, and president-elect of the American Ceramic Society, received the Distinguished Life Member Award of Alpha Sigma Mu, the international honor society for materials science and engineering. The honor recognizes his pioneering and seminal contributions, mentoring, and global leadership in the field of science, engineering, and applications of advanced materials and technologies for aerospace and energy systems.

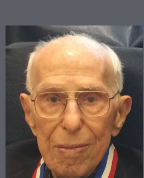
Fred E. Schmidt, FASM, president of Alpha Sigma Mu, and Dr. Singh

Suresh inducted into Institute of Medicine

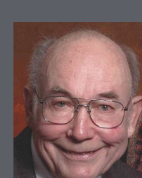
In October, Carnegie Mellon University President Subra Suresh, FASM, was inducted into the Institute of Medicine (IOM), making him the only university president to be elected to all three national academies—IOM, the National Academy of Sciences, and the National Academy of Engineering. Suresh is one of only 16 living Americans to be elected to all three national academies, and the first CMU faculty member to hold membership in all three. Before becoming president of CMU in 2013, he served as director of the National Science Foundation.

In Memoriam

Harvey Walter Schadler, FASM, of Niskayuna, N.Y., died on November 30, 2014, in Albany, N.Y., at age 83. He was born on January 4, 1931, in Cincinnati and attended Cornell University as a John McMullen Scholar, graduating magna cum laude with a B.S. in physical metallurgy in 1954. Schadler earned a Ph.D. in metallurgical engineering from Purdue University in 1957 and received their Distinguished Engineering Alumnus Award in 1992. Upon graduation, Schadler moved to Schenectady, N.Y., and worked at the General Electric Corporate Research and Development Center. He held many positions there and retired in 1996 as a technical director.



Dr. Bernard Queneau, FASM, Life Member, of Pittsburgh, passed away on December 7, 2014, one day after being honored as a Distinguished Eagle Scout. In October, he delivered a technical paper at MS&T at the age of 102. He earned both his B.S. and M.S. in metallurgical engineering from Columbia University in 1932 and 1933, and his Ph.D. in metallurgical engineering from the University of Minnesota in 1936. He joined ASM in 1934. Queneau worked for US Steel until 1938, returned to Columbia as an assistant professor, volunteered for war service in 1939, and was called for active duty in 1942. He developed steel grades for oxygen cylinders for pilots flying at high altitudes and received the Navy Commendation Medal. After the war, he rejoined US Steel and retired in 1977. Queneau received the Edgar C. Bain Award in 1977 from the Pittsburgh Chapter.



Arthur E. Schneider, Jr., Life Member, of Mattapoisett, Mass., passed away on December 2, 2014, at age 78. Raised in Michigan, he graduated from Wayne State University in Detroit and was active with the Alpha Sigma Phi fraternity and alumni association. He was first employed as a metallurgical engineer with General Motors at the Fisher Body Division in Michigan and worked in heat treating, failure analysis, and corrosion analysis with a focus on the formability of body steels. He then worked at Continental Screw Co. in New Bedford, Mass., and the Reed-Rico Rolled Thread Die Co. in Holden, on fastener design and developing thread-rolling dies. Schneider was a member of the Detroit Chapter, then Worcester, and in later years the Rhode Island Chapter, where he was recently recognized for his lifetime accomplishments in metallurgical engineering.

HIGHLIGHTS CHAPTER NEWS

North India Chapter Debuts

ASM International launched a North India Chapter at a special dinner at Vasant Vihar Club on September 26, 2014. The event included a technical talk on "Material Needs of the Indian Defense Sector: An Update" by Dr. K. Muraleedharan, director, Tech Materials Group, DRDO. New officers include L.Pugazhenthy, president; Rakesh Gupta and Anil Gupta, vice presidents; and Ankit Gupta, secretary. The Chapter will continue to organize technical programs following a successful International Conference on Advanced Heat Processing, held December 4-6, 2014, in Gujarat.

Valery Rudnev, FASM, Inductoheat Inc., answers questions at the well-attended heat processing conference organized by the new North India Chapter.

Dharma Maddala, senior scientist, Alcoa Technical Center, demonstrates the classification of materials based on their properties.

Pittsburgh Hosts Materials Mini-Camp

This year's camp was sponsored by several local companies including MatCo, Vesivius, American Stress Technologies, and Zircar Ceramics, as well as the ASM

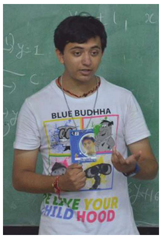
Foundation, ACerS, and AIST. Roughly 350 students from 17 schools enjoyed 10 demonstrations including heat treatment, corrosion, casting, refractory materials, and polymers. Presentations were led by master teacher Bob Wesolowski. During the event, one MS&T participant stated she is currently a materials science graduate student at the University of Akron and chose the major after attending a materials camp several years ago.

Detroit Tours ASM Birthplace

On November 10-11, 2014, ASM president Sunniva Collins visited the Detroit Chapter and several materials-related institutions. She delivered a talk and live demonstration on orbital welding applications during a dinner meeting. The next day, she was hosted by Chapter chair Manish Mehta and several committee members at the headquarters of Park Metallurgical/HeatBath Corp., a 100-year-old chemical and heat treating company in Detroit owned by William Park Woodside in the early 20th century. Woodside founded the Steel Treaters Society in 1913 in Detroit, which eventually became the global materials information society ASM is today.

ASM President Sunniva Collins addresses the Detroit Chapter.

Gujarat Highlights ASM Benefits



In September 2014, the Gujarat Chapter's most active student member, Viraj Dave, gave a lecture to raise awareness of ASM among college students. Dave is in his final year of studying mechanical engineering at Charotar University of Science and Technology, Gujarat, India. He delivered the lecture to 120 participants who came from different area colleges.

Rhode Island Enjoys Museum Tour

The Rhode Island Chapter held its September 2014 meeting at the New England Wireless and Steam Museum in East Greenwich, an electrical and mechanical engineering museum emphasizing the beginnings of radio and steam power. The facility preserves the original Massie coastal wireless station, which was moved from Point Judith, R.I. This station, built in 1907 to communicate with marine shipping, is the oldest originally equipped wireless station anywhere. It demonstrates the beginnings of the electronics industry including radio, TV, cellphones, Satcom, the Internet, computers, and other marvels of electrical and materials engineering.

Museum director Robert Merriam demonstrates a Handy Talkie, built by Motorola in 1944 and used in World War II.

ASM INTERNATIONAL Online Databases

Key Content Updates for 2014

ASM continues to expand the breadth and depth of its online materials science and engineering content, delivering relevant, peer-reviewed information and insight via regular updates. All updates are automatically included with each online database subscription. Key updates in 2014 include:

- ASM Alloy Phase Diagram Database: More than 1500 diagrams added, bringing the total to more than 39,000 binary and ternary diagrams and associated phase data
- ASM Handbooks Online: Added four NEW volumes, exclusively focused on practical and theoretical heat treatment information
- ASM Medical Materials Database: Two NEW modules—Surgical and Neurological devices and associated materials
- ASM Micrograph Database: Nearly 200 NEW micrographs and associated data, with a focus on composites
- ASM-NACE Corrosion Analysis Network: Updated regularly, now features more than 21,000 documents from ASM, NACE, ASTM, and SSPC

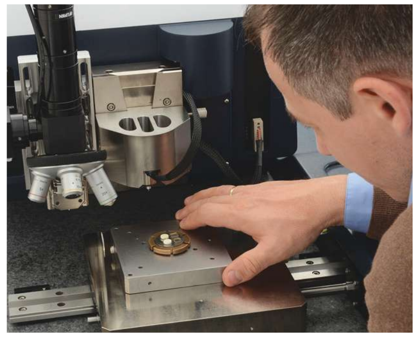
For more information, contact Denise Sirochman at denise.sirochman@asminternational.org, 800.336.5152 or 440.338.5151 ext. 5230.

PRODUCTS & LITERATURE

The EM TIC 3X **ion beam milling system,** from Leica Microsystems Inc., Buffalo Grove., Ill., is now available with a docking port for vacuum cryo transfer. The new port enables transfer at vacuum and/or cryo conditions with the Leica EM VCT100 vacuum cryo transfer system. Room temperature or cryo sections can be taken directly from the ion beam milling system, loaded into the vacuum cryo transfer system, and transferred to the next preparation step. The new system enables high-quality surface preparation of hard, soft, porous, heat sensitive, brittle, and heterogeneous materials for microstructure analysis by means of scanning electron microscopy and atomic force microscopy. *leica-microsystems.com.*

Continental Structural Plastics (CSP), Auburn Hills, Mich., introduces its Tough Class A (TCA) Ultra Lite, a **1.2 specific gravity (SPg) SMC formulation** that gives engineers the ability to design with a lower specific gravity material without sacrificing mechanical properties, surface qualities, or adhesion requirements. Depending on the body component being developed, design studies show that CSP Ultra Lite offers weight savings up to 21% over the company's mid-density TCA Lite (1.6 SPg) and 35% over its standard TCA material (1.9 SPg). *cspplastics.com.*

Bruker Corp., Madison, Wis., introduces the NanoForce nanoindenting and



nanomechanical testing system to enable full-scale studies of nanoscale material behavior on a wide range of specimen geometries, including thin films, nanostructures, MEMS, and various device components. The system features NanoScript measurement and control software, which enables real-time experimental control based on recorded or calculated data. A gantry design and enclosure cabinet provide excellent positional accuracy as well as acoustic and vibration isolation to establish an optimal testing environment. A vacuum tray offers convenience for mounting samples, and built-in safety features protect the head assembly during translation of the *X-Y* stages. *bruker-nano.com.*

Lucideon, UK, published a new **white paper,** *Understanding Materials Choices, Their Performance and Selection.* Central to recent progress in material-driven innovations and applications is improving the ability to define materials in terms of composition, structure, and performance. This free white paper affirms the value of materials characterization in product and process development activities in technology-based industries. *lucideon.com/testing.*

Altatech, a division of Soitec, France, launched the Orion Lightspeed **inspection system,** capable of pinpointing the size and location of nanoscale defects inside compound semiconductor materials and transparent substrates. The system improves the performance and cost efficiency of identifying defects within III-V materials, transparent substrates, and thin circuit layers on top of transparent substrates. Inspection is performed using synchronous Doppler detection technology, which determines the exact size and position of defects by making direct physical measurements with resolution below 100 nm. The system can handle substrates up to 300 mm. *soitec.com.*

AD INDEX

ADVANCED MATERIALS & PROCESSES EDITORIAL PREVIEW

FEBRUARY 2015

Advances in Microscopy/ Metallography/Materialography

Highlighting:

- Measurement of Decarburization
- Jacquet-Lucas Award Winner
- ITSC 2015 Show Preview

Advertising Bonus:

- Signet Ad Study

Special Supplement:

International Thermal Spray and Surface Engineering newsletter covering coatings in the aerospace and defense industries.

Bonus Distribution:

- AeroMat, ITSC 2015, and IMS Regional May 11-15, Long Beach, Calif.
- M&M 2015 + IMS Annual Meeting August 2-6, Portland, Ore.

Advertising closes January 5

MARCH 2015

Modern Materials for Energy/Automotive/Power Generation

Highlighting:

- Materials Research for Advanced Power Engineering
- Joining Dissimilar Materials
- Corrosion Resistant Alloys

Special Supplement:

HTPro newsletter covering heat treating technology, processes, materials, and equipment, along with Heat Treating Society news and initiatives.

Advertising closes February 4

STRESS RELIEF

3D PRINTING DINOSAUR FOSSILS

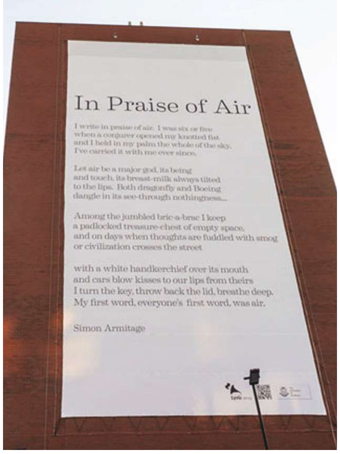
MakerBot, Brooklyn, N.Y., introduced T-Rex Skeleton, an anatomically correct, scaled model of a full Tyrannosaurus rex skeleton. The T-Rex lived in North America more than 65 million years ago. The giant has long been a favorite of 3D modelers, but is difficult to sculpt and 3D print. In addition to the T-Rex skeleton, the company also introduced a T-Rex skull. Both fairly complex models showcase advanced sculpting and are geared toward education, functional use, and scientific content. The T-Rex skeleton model contains 19 files for a total of 79 pieces, which are numbered, labeled, and come with assembly instructions. ***makerbot.com.***

Two new 3D printable models, a T-Rex skeleton and a T-Rex skull, were released by MakerBot. Courtesy of Business Wire.

CALCULATING THE STRENGTH OF SPIDER-MAN'S WEB

Spider webs are notoriously strong, with spider silk reported as having a tensile strength of up to 1.75 GPa. Carbon nanotubes (CNTs) are even stronger, handling 63 GPa or more. Though according to the 1986 *Official Handbook of the Marvel Universe,* Spidey's webs are made of a nylon-like material that can support a measly 0.5 GPa. But can the strength of a specific material alone account for the properties of Spidey's web? The structure of the web is also clearly important. But what is the web actually made of? One hypothesis is that the web may be made of carbon nanotubes. If so, we may see something Spidey-esque sooner rather than later. *For more information: Suveen Mathaudhu, snmathau@ncsu.edu, ncsu.edu.*

Cover image of Amazing Spider-Man #520 by Mike Deodato. Courtesy of marvel.com.



FIGHTING AIR POLLUTION WITH POETRY

Simon Armitage, poetry professor at the University of Sheffield, UK, collaborated with science professor Tony Ryan to create a catalytic poem called *In Praise of Air*—printed on material containing a formula invented at the university that is capable of purifying its surroundings. This inexpensive technology could also be applied to billboards and advertisements alongside congested roads to cut pollution. The 10 × 20 m (38 × 66 ft) piece of material that the poem is printed on is coated with microscopic pollution-eating particles of titanium dioxide, which use sunlight and oxygen to react with nitrogen oxide pollutants and purify the air. "This poem alone will eradicate the nitrogen oxide pollution created by about 20 cars every day," says Ryan. *For more information: Tony Ryan, t.ryan@sheffield.ac.uk, www.sheffield.ac.uk.*

SUCCESS ANALYSIS

SPECIMEN NAME: NSL ANALYTICAL SERVICES INC.

X-ray analysis can be used for ceramic and glass materials.

VITAL STATISTICS

In business since 1945, NSL Analytical is not only one of the oldest independent materials testing laboratories in the U.S., but also one of the most comprehensive under one roof. Unlike some other labs that only offer certain services in specific geographic areas, NSL is known for its broad range of testing capabilities to serve the aerospace, nuclear, refractory, medical, and metalworking industries, among others. The company's success can be attributed to delivering consistent results demanded by these industries. Another advantage is the ability to produce results in three to five days in most cases, rather than weeks.

The company began as a chemistry lab offering trace element analysis. Over the years, metallurgical evaluations, failure analysis, mechanical testing, consulting services, polymers testing, thermal analysis, and several other specialized materials testing services were added to meet the needs for product improvements and research. In 2013, the company invested more than $1.6 million in an expanded and dedicated metallurgical testing facility just down the street from the analytical lab. The facility has more than 43,000 ft^2 of testing space for instruments and evaluations.

Analyzing samples on the GC-MS in the NSL organic lab.

SUCCESS FACTORS

Company leaders say they can trace success to their anchors of "trust, technology, and turnaround." With the development of an underlying and robust quality system, the lab is able to keep a continuous focus on testing quality. By actively participating in Nadcap committees, ISO, and the ASTM standards organization, the company is helping guide the industry in testing methodologies. Investments continue to me made in a computerized LIMS system (laboratory information management system), state-of-the-art instrumentation, and ongoing training of chemists, metallurgists, and technicians.

ABOUT THE INNOVATORS

Traditionally, many companies have had to split their testing needs between several different suppliers to meet various requirements, but NSL is able to identify, characterize, and perform other related functions in one stop using a wide range of capabilities and strategic partnerships.

WHAT'S NEXT

NSL's technical team and the collective power of its scientists to solve challenging problems is helping facilitate growth into new and emerging markets.

Contact Details

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